Deep Space Network

Deep Space Network Services Catalog

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Document Change Log

Revision	Check (X) If Minor Revision	Issue Date	Affected Sections or Pages	Change Summary
-		09/03/98	All	Initial issue of document
A		5/19/03		Version 7.5
B		07/03/07	All	Change scope of the Catalog contents to DSN services only.

Document Overview

1. Introduction	Purpose and scope of the document Characterization of this version Terminology
2. DSN Overview	Background and context Service concepts Listing of capabilities by category
3. Data Services	Descriptions of standard services relating to transport and acquisition of data via space links
4. Engineering Support	Descriptions of engineering support in the form of direct participation in mission activities
5. DSN Stations	Operating Modes and Characteristics
6. Obtaining Services and Support	References to policies pertaining to the availability and pricing of capabilities (both standard and non-standard) How to obtain capabilities in terms of commitment, scheduling, and "provision" (delivery and execution)
7. Appendices	A. Glossary and Acronyms B. Document Information and References

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Section 1
Introduction

1.1 Purpose

This Services Catalog provides a comprehensive overview of the capabilities available from the Deep Space Network to support flight projects and experiment investigations. The capabilities described here are focused on deep space missions, near-Earth missions above Geosynchronous Earth Orbit (GEO) distance, and ground-based observational science, although many are potentially applicable to other mission domains.

The descriptions given in this Services Catalog are intended to aid those preparing mission and experiment proposals, as well as those in the early stages of project planning. More specifically, the Services Catalog:

- Provides a standard taxonomy of services. It serves as the basis for service-level agreements and other instruments of commitment between flight project and experiment investigation customers and the service providers.
- Provides high-level descriptions of the capabilities. It will assist mission proposers and planners in scoping their efforts and in establishing conceptual designs for areas concerning space communications. In addition, since the DSN services and capabilities are constantly evolving, the Catalog is a means to communicate with missions for new things to come and old to decommission, so that the affected missions can plan for such changes in alignment with the DSN.
- Provides basic information regarding how to obtain services and support. It aids pre-project customers in planning. It includes information regarding pricing that can be used in deriving life-cycle cost estimates for mission systems. This is crucial in an era of full cost accounting, as the mission selection process conducted by the various National Aeronautics and Space Administration (NASA) Programs must take into account their expenditures on multi-mission support.

1.2 Scope

The capabilities identified in this Services Catalog come from the Deep Space Network (DSN), a multi-mission system, which provides space communication services, i.e. acquisition and/or transport of tracking, telemetry, and command (TT&C) data over the space links, as well as observational science utilizing those links.

The capabilities provided to customers are data services. These are operational functions that relate directly to the communications and tracking over space-ground communications links, and to the acquisition of observational data pertaining to such links. These functions are performed in their entirety by the service provider.

In accordance with established policy, this Services Catalog includes only capabilities that are either available or have funded deployment plans and approved commitment dates at the time of its release.

Note that the Services Catalog is not a requirements, design, or interface specification. The various documents more fully defining the capabilities and their interfaces are discussed in Section 2, "DSN Overview", and identified in Section 3, "Data Services". The various instruments of commitment and their usage are discussed in Section 6.4, "Commitment Process".

1.3 About This Version

This version, although considered as the first release of the DSN Services Catalog, in fact inherits a significant portion of the technical information from its predecessor documents, i.e., the DSMS Services Catalog and the earlier TMOD Services Catalog. It differs from its predecessors in the following aspects:

- The scope has been limited to DSN data services. Mission services, e.g. navigation, sequencing, etc., and Advanced Multi-Mission Operations System (AMMOS) tools in the DSMS Services Catalog have been removed.
- The Services Catalog has been restructured to make the information hopefully more accessible and understandable.
- For some services, their functional description and performance characteristics have been updated to reflect changes in existing capabilities or new capabilities. Moreover, additional technical information have also been incorporated..
- The section about obtaining DSN services and engineering support has been rewritten.

1.4 Notation and Terminology

Throughout this Services Catalog, references to external documents are noted by footnotes. A complete list of references is shown in Appendix B, "Document Information".

Terms and acronyms used within this Services Catalog are defined in appendix A, "Glossary & Acronyms". However, the reader should be particularly aware of some key terms. They are:

Capability.............	Used generically in the Services Catalog to refer to any and all services and support used by missions
Customer..............	An organization that requires capabilities from the DSN in order to conduct a flight project or experiment investigation
Decommissioned...….	Applies to a capability or facility that is no longer supported for use by any customer
DSN Science ....….	Refers collectively to Radio Science services, Radio Astronomy / Very Long Baseline Interferometry (VLBI) services, and Radar Science services, or the data and meta-data generated by these services
Mission.................…	Used generically in the Services Catalog to refer to a flight project, and an experiment investigation conducted in conjunction with a flight project, or an experiment investigation using the DSN as a science instrument
Mission Data ....…	Data that are transported via the space-ground communications link, or are derived from observation of that link – including command data (but not all information pertaining to command preparation), telemetry (level 0 or thereabouts), tracking data (but not navigation data), and DSN science data
User......................…	A person participating in flight project mission operations or an experiment investigation, who interacts directly with services or support provided by the DSN

Section 2
DSN Overview

This section provides a description of the DSN in the context of mission operations, a physical view oft the DSN, and the service concept of the DSN.

2.1 Mission Operations Context

2.1.1 Functional View

Figure 2.1 depicts a functional view of the DSN in the context of mission operations. The breakdown shown is typical for a flight project, although there can be substantial variety resulting from a particular mission's characteristics, organization, and operational strategy.

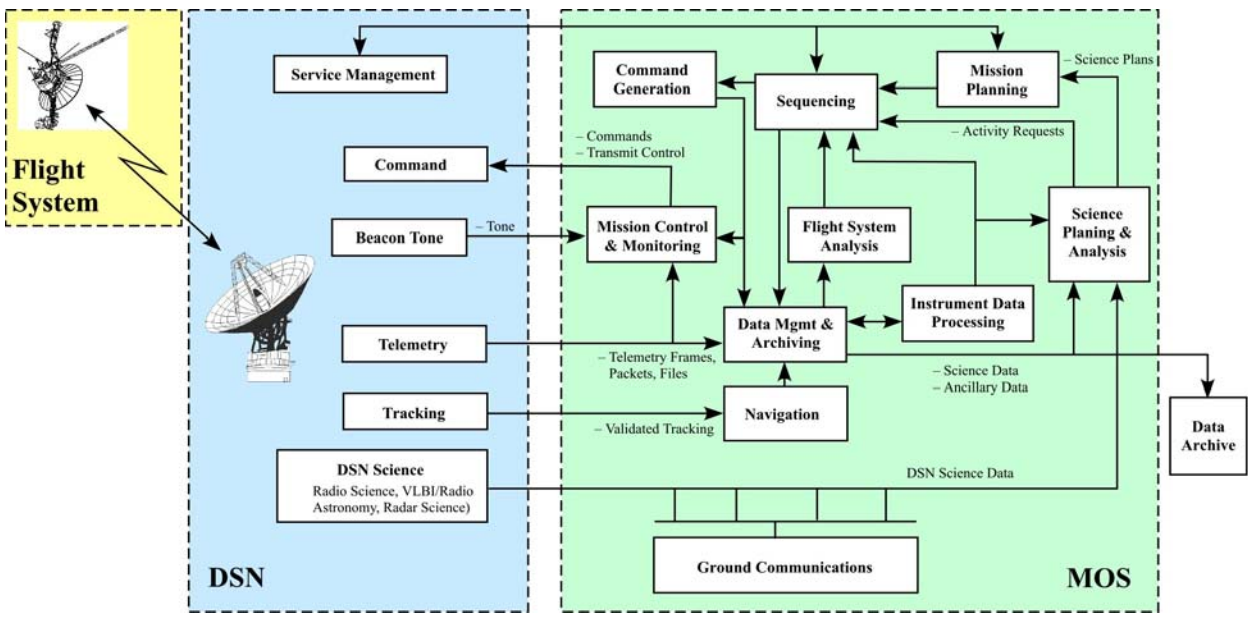

Figure 2-1. Mission Operations Context – Functional View

Three distinct operational domains are shown in the diagram above:

- Flight system – The flight system performs as a semi-autonomous operations system. It carries out a wide variety of functions (such as command or sequence execution, making in situ or remote measurements or other observations, on-board data management, and the on-board aspects of space communication, etc.) that vary by mission. The flight system communicates directly with the DSN via the space-ground communications link, and indirectly with the flight project's Mission Operations System (MOS) through the DSN.
- DSN – The DSN operates on a multi-mission basis, serving many flight projects and experiments concurrently. The DSN carries out a standard set of functions on the customer's behalf (e.g. command and telemetry data transport, tracking, and ground-based science data acquisition). These are coordinated via a common service management function (this is not explicitly shown in the diagram, but is described further later on). The DSN communicates with the flight system directly via the space-ground communications link, and with the MOS via a set of standard service interfaces.

- Mission Operations System (MOS) – The flight project's or experiment investigation's MOS operates largely as a dedicated operations system. The MOS carries out the ground engineering functions necessary to operate a mission (such as planning, sequence and command generation, navigation, and analysis of flight system performance and behavior). Science planning and analysis may also be carried out by the MOS (as shown), or may be relegated to a separate Science Operations System which interacts closely with the MOS. The MOS communicates directly with the DSN via the service interfaces, and indirectly with the flight system through the DSN.

2.1.2 Physical View

Figure 2.2 depicts a physical view of the DSN in the context of mission operations, identifying the key facilities used in supporting flight projects and experiment investigations.

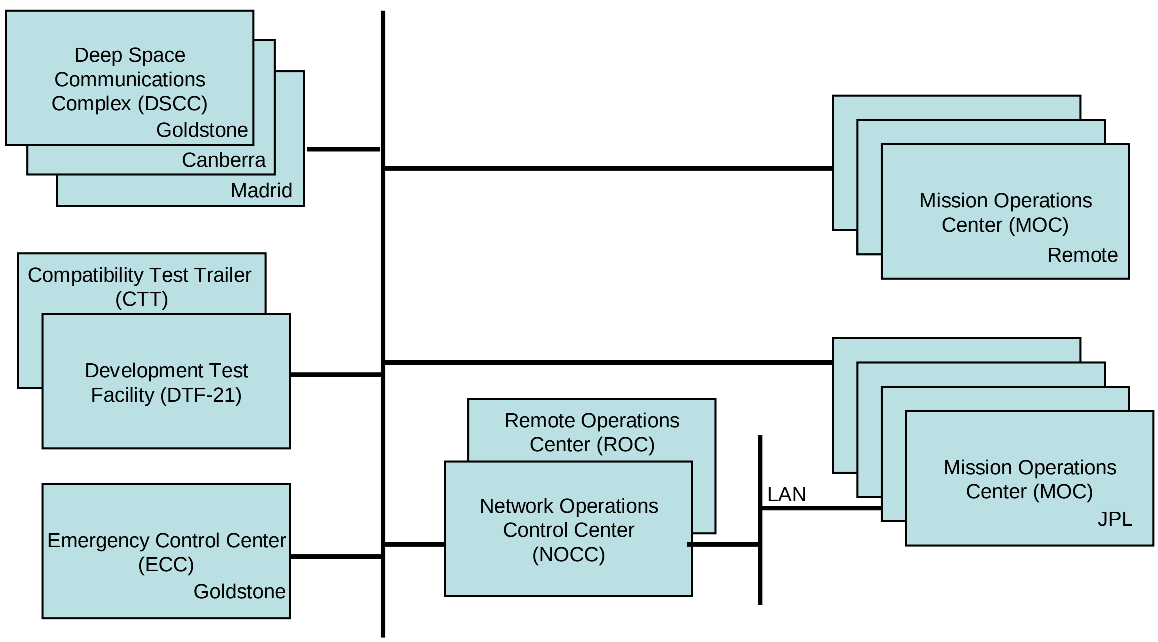

Figure 2-2. Mission Operations Context – Physical View

The facilities shown in the figure are described as follows:

- Deep Space Communications Complexes (DSCC) – The three DSCC facilities are located near Barstow in Goldstone, California; Madrid in Spain; and Canberra in Australia. Each complex has a Signal Processing Center (SPC) and a number of antennas, including at least a 70m antenna, a 34m High Efficiency (HEF) antenna, and a 34m Beam Wave Guide (BWG) antenna. It also has the support infrastructure and personnel needed to operate and maintain the antennas.
- Figure 2.3 identifies the antenna sizes and types available at each of the locations. These stations communicate with and track spacecraft at S- or X-band (in 34m and 70m cases both). A few of the 34m BWG stations are also equipped with Ka-band capability. See section 5.1, "DSN Stations – Operating Modes and Characteristics" for a summary of the characteristics and RF capabilities of

each antenna. A more detailed specification of the key characteristics of the DSN antennas can be found in the DSN Telecommunications Link Design Handbook[1].

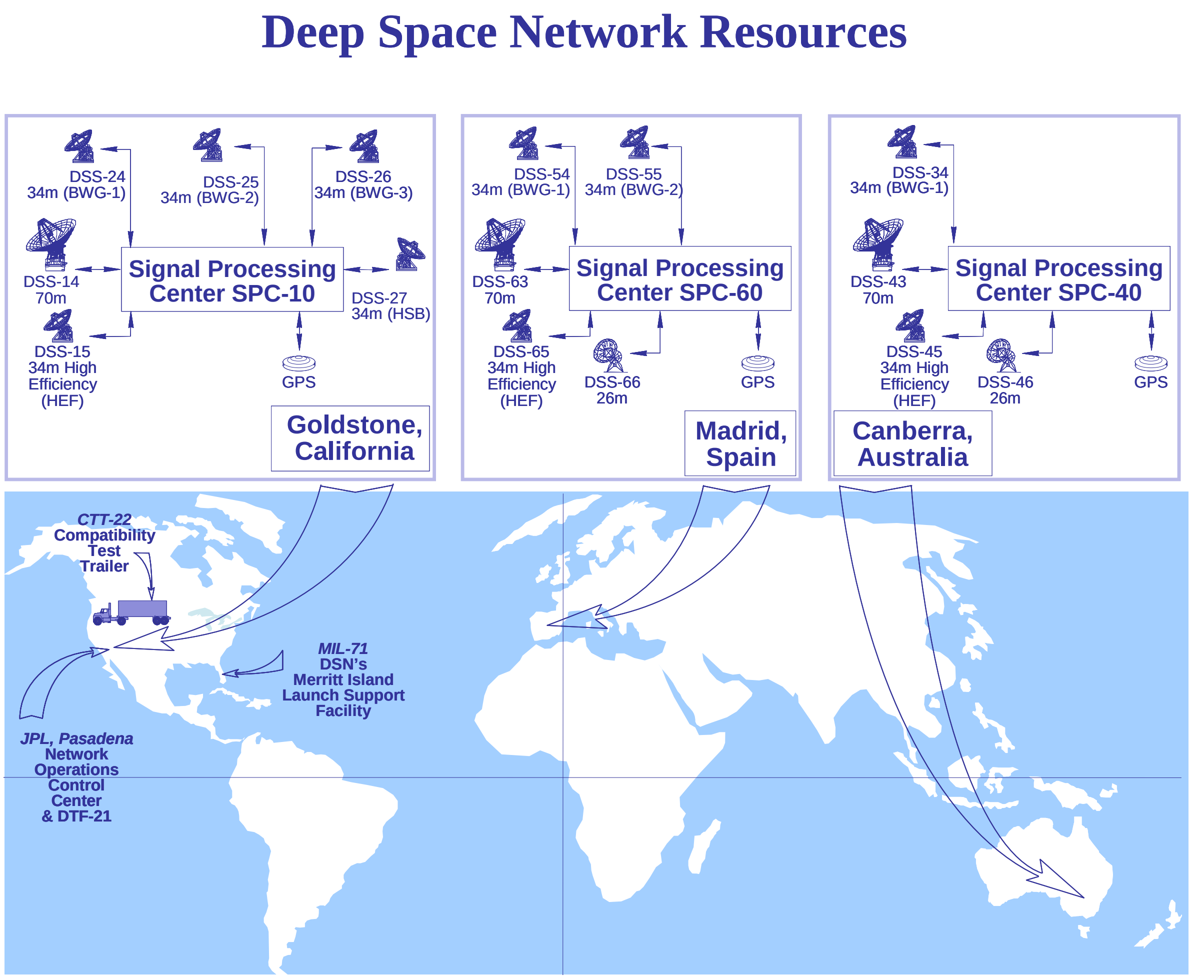

Figure 2-3. DSN Asset Types and Locations

[1] DSN Telecommunications Link Design Handbook, Document No. 810-005, Rev. E, Jet Propulsion Laboratory, Pasadena, California. Online at http://eis.jpl.nasa.gov/deepspace/dsndocs/810-005/

DSN Test Facilities

- The Development Test Facility (DTF-21), located near JPL, is used to conduct tests of RF compatibility between the DSN and the customer's flight system, and as a development test facility for modifications to be implemented in the DSN.
- The Compatibility Test Trailer (CTT-22) is a transportable facility for conducting tests of RF compatibility between the DSN and the customer's flight system at the customer's facility.
- MIL-71 is located at Merritt Island, Florida, provides DSN-compatible launch support for launch operations at NASA's Kennedy Space Center.

- Emergency Control Center (ECC) – This DSN facility is located at Goldstone, California. It is a scaled-down mission operations center intended to enable limited flight operations in the event that a natural disaster or other catastrophe disables operations at JPL.
- Network Operation Control Center (NOCC) – This is a collection of facilities located at or near the JPL Oak Grove site in Pasadena, California. These house the computing and communications components and the personnel, that provide central monitor and control of the network, and coordination between the globally distributed DSCC's, as well as data processing.
- Remote Operations Center (ROC) – This comprises the facilities, equipment, and personnel that provide day-to-day operations engineering and support functions for the DSN.
- Mission Operation Centers (MOC's) – These customer facilities house the MOS. They are typically assigned to a single flight project, although shared MOC's are sometimes used. Depending on the project, MOC's may be located at JPL in Pasadena, California; at a spacecraft vendor's site; at the customer's home institution; or some combination thereof.

  An alternative term that is commonly used in reference to JPL missions is Mission Support Area (MSA). This can be thought of as a synonym for "MOC", or as a reference to a dedicated area with a larger MOC serving multiple missions.
- Wide Area Network Communications – Once referred to as the Ground Communications Facility, the long-haul communications connecting the DSCC's, JPL Central, other DSN facilities, and the customer's MOC are now provided by the NASA Integrated Services Network (NISN).

2.2 Service Concepts

The DSN provides a variety of different types of capabilities covering a broad range of mission functions. In the past, distinctions among these various types of capabilities were rather vague. This document attempts to establish a more rigorous taxonomy of capabilities in order to more effectively communicate to customers what is available and what must be done to utilize it, to provide frequently needed capabilities more quickly and cost-effectively, and to assist in responding to NASA's mandate for full cost accounting.

The capabilities provided by the DSN are classified as follows:

- Data Services
- Engineering Support

2.2.1 Data Services

Generally, "service" means "work done on behalf of another". Within this Services Catalog, we use a more stringent definition that conforms to the precepts of service-oriented systems architectures:

Service – A self-contained function, which accepts one or more requests and returns one or more responses through a well-defined, standard interface. A service does not depend on the context or state of other services or processes (although it may utilize other services via their interfaces).

Services are specified from the user's point of view, i.e., in terms of "what it provides" rather than "how it is performed" or "what does the job". Another way of saying this is that a service is completely specified in terms of its behavior and performance without reference to a particular implementation.

The services described herein are "mission operations" services, i.e., a service provider (e.g., the DSN) produces engineering or science operations results for a flight project or experiment investigation. The service is the "whole job" in the operations sense. It will thus typically involve a combination of software components, computing and communications hardware, personnel and the procedures they follow, as well as facilities. Further, the service is also the "whole job" in the life-cycle sense. The design, implementation, integration, verification and validation activities needed to supply the service are an inherent part of it.

"Data Services" are mission operations services that relate directly to the transport of mission data over space-ground communications links, and to the acquisition of observational data pertaining to such links. They exhibit the following common characteristics:

- "Pick & Choose" – The data services offered by the DSN are independent of each other, i.e., subscribing to one service does not imply a need to also subscribe to additional, unrelated services. Customers can thus pick and choose those services that are relevant to their purposes and cost-effective to use.
- "Plug & Play" – DSN-provided data services are multi-mission in nature. This means that they require little or no adaptation, provided they are used in accordance with their standard definition. No development is required on the part of the DSN beyond simple configuration, parameter updates, and support for interface testing. The development needed on the customer's side is limited to that inherent in using the standard service and meeting its interfaces.
- Standard Interfaces – DSN-provided data services are accessed via well-defined, standard data and control interfaces. "Standard interfaces" in this usage include those formally established by standards organizations (e.g. the Consultative Committee for Space Data Systems (CCSDS), the Space Frequency Coordination Group (SFCG), the International Telecommunication Union (ITU), the International Organization for Standardization (ISO)), de facto standards widely applied within industry, and common interfaces specified by the DSN[2]. Where feasible, data service interface standards have been chosen so as to enable a high degree of interoperability with similar services from other providers. This mitigates the need for additional development effort on the part of both the DSN and the customer, as well as maximizing the customer's opportunities to reuse service utilization applications.
- Accountable – The performance of each data service to which a customer subscribes is routinely measured and reported. In addition, since services are provided on a fee schedule basis, the recurring costs of providing a particular service are also tracked.

2.2.2 Engineering Support

DSN engineering personnel can be made available to support customers in conducting pre-project studies, mission design, MOS/GDS development, integration and test, as well as mission operations. These are most commonly conducted on a level-of-effort basis, but may entail specific deliverables. The scope of each engineering support activity must be assessed on a case-by-case basis, and availability of personnel is naturally limited.

[2] Deep Space Network / Detailed Interface Design, Document No. 820-013, Jet Propulsion Laboratory, Pasadena, California

2.3 List of Services and Support

The following sections list the services and support capabilities offered by the DSN.

2.3.1 List of Standard Data Services

- **Command Services**
  - Command Radiation Service
  - Command Delivery Service
- **Telemetry Services**
  - Bit Stream Service*
  - Frame Service
  - Packet Service
  - Telemetry File Service
  - Beacon Tone Service
- **Tracking Services**
  - Raw Radio Metric Measurements Service*
  - Validated Radio Metric Data Service
  - Delta-DOR Service
- **Calibration and Modeling Services**
  - Platform Calibration Service
  - Media Calibration Service
- **Radio Science Services**
  - Experiment Access Service
  - Data Acquisition Service
- **Radio Astronomy / VLBI Services**
  - Signal Capturing Service
  - VLBI Data Acquisition Service
  - VLBI Data Correlation Service
- **Radar Science Services**
  - Experiment Access Service
  - Data Acquisition Service

* This service is slated for decommissioning and is not available to new customers

2.3.2 List of Engineering Support

- System Engineering Support
- Advanced Mission Planning Support
- Emergency Mission Operations Center Support
- RF Compatibility Test Support
- Mission System Test Support
- Spectrum and Frequency Management Support
- Spacecraft Search Support

Section 3
Data Services

This section describes the standard data services provided by DSN. The individual data services are grouped into eight service families. Each family is a collection of functionally related services. The various services within a family are distinguished from one another by the level of processing involved, their value-added function, or the type(s) of source data.

3.1 Command Services

The Command Services transmit data to the spacecraft. Command data transmitted typically includes commands, sequence loads, and flight software loads, but may also include any other types of data elements. This service family is functionally divided into Command Radiation service and Command Delivery service. The following summarizes these services in terms of their associated data modes and protocols:

Table 3-1. Command Services Summary

Command Service Type	Data Mode	Protocol and Interface Specification
Command Radiation Service	Stream Mode	Throughput: JPL CMD-4-9[3] CCSDS SLE Forward CLTU Service[4]
	File Mode	AMMOS Space Command Message File (SCMF) Interface
Command Delivery Service	File Mode	CCSDS File Delivery Protocol (CFDP)[5]

3.1.1 Command Radiation Service

Command Radiation is the more rudimentary of the two services. DSN operates this service in either a Stream Mode or a File Mode. In the stream mode, data in the form of Command Link Transmission Units (CLTUs) is received from a customer's MOS and radiated in real-time to a spacecraft as a string of data units. Conversely, in file mode, a command file, i.e., the Space Command Message File (SCMF), is stored at DSN NOCC prior to, or during, a pass and radiated to the spacecraft at a customer-specified time. Both modes ensure timely radiation of command data; however, error-free command delivery to the spacecraft is not guaranteed.

The Throughput interface is slated for decommissioning and is not available to new customers. The CCSDS Space Link Extension (SLE) CLTU has been the standard interface protocol in stream mode, with the DSN Command Radiation Service since 2002.

Table 3.2 contains a set of attributes summarizing the functions, performance, and interfaces for the Command Radiation Service. Relevant documents for this service are also identified in the table.

[3] Deep Space Network / Detailed Interface Design, Document No. 820-013, CMD-4-9, "Command Radiation Service – Throughput Stream Mode Protocol", July 2000

[4] Space Link Extension Forward CLTU Service Specification, CCSDS 912.1, Red Book, Issue 1.99h, February 2000

[5] CCSDS File Delivery Protocol (CFDP), CCSDS 727.0-B-2, Blue Book, October 2002

Table 3-2. Attributes of the Command Radiation Service

Parameter	Value
Frequency Bands Supported	Near-Earth S, X Deep space S, X
EIRP and Transmitting Power	S-Band: 26m 94 dBW at 20 kW 34m BWG 99 dBW at 20 kW 34m HEF 78 dBW at 200 W* 70m 106 dBW at 20 kW X-band: 34m BWG/HEF 110 dBW at 20 kW 70m 116 dBW at 20 kW refer to Table 5.1.
Polarizations Supported	RCP LCP No RCP/LCP simultaneity, refer to Table 5.1.
Modulation Types	BPSK on subcarrier for uplink rate ≤ 4 kbps BPSK directly on carrier for uplink rate 4 kbps to 256 kbps
Modulation Formats	NRZ: L, M, S Bi-phase L or Manchester, M, S
Modulation Index Range	0.1 - 1.4 radians
Carrier/Subcarrier Waveform	Residual carrier: sine wave Subcarrier: 8 or 16 kHz
Uplink Acquisition Types	CCSDS Physical Link Operations Procedure-1 (PLOP-1) or CCSDS Physical Link Operations Procedure-2 (PLOP-2)
Uplink Data Rate	Maximum 256 kbps Minimum 7.8 bps
Channel Coding	Provided by mission user
Forward Error Correction Code	Provided by mission user
Data from MOC to DSN	Stream of CLTUs over a TCP/IP interface or File of CLTUs
Data from DSN To Spacecraft	CLTU per CCSDS TC Space Link Protocol (ref. CCSDS 232.0-B-1) CLTU per CCSDS AOS Space Data Link Protocol (ref. CCSDS 732.0-B-2)
Data Unit Size	Maximum CLTU size: 32,752 bits Minimum: 16 bits A series of CLTUs can be contiguously radiated.

Parameter	Value
Data Retention Period	No data retention other than buffer staging for radiation
Data Delivery Methods from MOC to DSN	CCSDS Space Link Extension (SLE) Forward CLTU (ref. CCSDS 912.1-R-1.99h), on-line delivery mode AMMOS Space Command Message File (SCMF) Interface, on-line or off-line delivery mode
Radiation Latency	≤ 125 milliseconds per CLTU
Service Operating Mode	Automated
Service Availability	Nominal 95% Mission critical event 98%
Data Completeness	Radiated CLTUs are verified providing a guarantee of successful radiation, but no guarantee of reliable command receipt at the spacecraft
Data Quality	Bit error rate: 10^{-7} CLTU error rate: 10^{-4}
Accountability Reporting	SLE command radiation status report
Ground Communication Interface Methods	Refer to Section 3.8
DSN Interface Specifications	DSN document 810-005; 820-013 0163-Telecomm

* Future capability, S-band uplink at 34m HEFs will be available for operations in early 2009

The Command Radiation Service offers two ranges of uplink data rates using different command modulation schemes – Low-Rate command and Medium-Rate command

1) Low-Rate Command – Uplink rates for Low-Rate Command range from 7.8 bps to 4 kbps. The uplink modulation scheme for this mode complies with the CCSDS recommendation[6]. Command data units from the customer's MOS are Phase Shift Key (PSK) modulated by the DSN on a 8 or 16 kHz sine wave subcarrier such that the subcarrier is fully suppressed. This PSK-modulated subcarrier is then modulated onto the RF carrier so as to leave a residual (remaining) carrier component.
2) Medium-Rate Command – Uplink rates for Medium-Rate Command range from 8 kbps to 256 kbps. The uplink modulation scheme for this mode complies with the CCSDS recommendation[7]. Command data units from the customer's MOS are modulated onto an RF carrier (instead of subcarrier) by the DSN so as to leave a residual (remaining) carrier component. The maximum uplink data rate, 256 kbps as shown in Tables 3.2 and 3.3, can only be met under limited circumstances:

[6] CCSDS Recommendation 401 (section 2.2.2) B-1, "Low-Rate Telecommand Systems" in Radio Frequency and Modulation System, Part 1 - Earth Stations and Spacecraft, CCSDS 401.0-B, June 2001

[7] CCSDS Recommendation 401 (section 2.2.7) B-1, "Medium-Rate Telecommand Systems" in Radio Frequency and Modulation System, Part 1 - Earth Stations and Spacecraft, CCSDS 401.0-B, June 2001

a) Contiguous radiation of a sequence of CLTUs is ensured
b) The radiation duration of each CLTU (number of bits/data rate) must be greater than 100 msec
c) The maximum CLTU size that can be accepted is 32,752 bits

Moreover, data quality identified in Tables 3.2 and 3.3 assumes sufficient E_b/N_o floor provided for the space forward link.

3.1.2 Command Delivery Service

Command Delivery is a more comprehensive service. This service includes the functionality of lower level services, i.e., the Command Radiation Service, and the reliable command delivery feature. It accepts command files from a Project's MOS in either real-time or at any point prior to the time designated for radiation. The command files are stored at the NOCC until positive confirmation of successful file delivery to the spacecraft. Using the standard CCSDS File Delivery Protocol (CFDP)[8], this service executes command radiation while providing reliable "error-free" delivery of command data to a spacecraft. The reliable command delivery is accomplished through the selective retransmission scheme of CFDP. Therefore, missions subscribing to this service must implement that capability on the spacecraft compliant to the CFDP standard.

Table 3.3 contains a set of attributes summarizing the functions, performance, and interfaces for the Command Delivery Service. Relevant documents to this service are also identified in the table.

Table 3-3. Attributes of the Command Delivery Service

Parameter	Value
Frequency Bands Supported	Near-Earth S, X Deep space S, X
EIRP and Transmitting Power	S-band: 26m 94 dBW at 20 kW 34m BWG 99 dBW at 20 kW 34m HEF 78 dBW at 200 W* 70m 106 dBW at 20 kW X-band: 34m BWG/HEF 110 dBW at 20 kW 70m 116 dBW at 20 kW refer to Table 5.1.
Polarizations Supported	RCP LCP No RCP/LCP simultaneity, refer to Table 5.1.
Modulation Types	BPSK on subcarrier carrier for uplink rate ≤ 4 kbps BPSK directly on carrier for uplink rate 4 kbps to 256 kbps
Modulation Formats	NRZ: L, M, S Bi-phase L or Manchester, M, S

[8] CCSDS File Delivery Protocol (CFDP), CCSDS 727.0-B-2, Blue Book, October 2002

Parameter	Value
Modulation Index Range	0.1 - 1.4 radians
Carrier/Subcarrier Waveform	Residual carrier: sine wave Subcarrier: 8 or 16 kHz
Uplink Acquisition Types	CCSDS Physical Link Operations Procedure-1 (PLOP-1) or CCSDS Physical Link Operations Procedure-2 (PLOP-2)
Uplink Data Rate	Maximum 256 kbps Minimum 7.8 bps
Channel Coding	Provided by mission user
Forward Error Correction Code	Provided by mission user
Service Modes	Non-acknowledged Acknowledged
Data from MOC to DSN	Files per CCSDS File Delivery Protocol (CFDP) standard (ref. CCSDS 727.0-B-3)
Data from DSN To Spacecraft	Files per CCSDS File Delivery Protocol (CFDP) standard (ref. CCSDS 727.0-B-3)
Data Unit Size	Maximum PDU size: 32,752 bits Minimum: 16 bits
Data Retention Period	Data retention from the time of receiving the file to successful transmission
Data Delivery Methods from MOC to DSN	File transfer on-line during the pass or off-line before the pass
Service Availability	Nominal 95% Mission critical event 98%
Data Completeness	100% for acknowledged service mode (guaranteed delivery)
Data Quality	CLTU error rate: 10^{-4} (with BCH encoding) Undetected error rate: about $5x10^{-8}$
Accountability Reporting	Radiation log, event report, and CFDP transaction log
Ground Communication Interface Methods	Refer to Section 3.8
DSN Interface Specifications	DSN document 810-005 820-013 0188-Telecomm for CFDP

* Future capability, S-band uplink at 34m HEFs will be available for operations in early 2009

3.2 Telemetry Services

Telemetry Services acquire telemetry data from a CCSDS compliant space link, extract communications protocol data structures, and deliver them to a customer's MOS. Three different levels of services are available, plus a bit stream service for legacy missions only. Subscription to a particular level automatically includes the lower level services. The services available are:

- Bit stream (no longer offered to new customers)
- Frame
- Packet
- File

Accountability for performance is an essential aspect of the service paradigm. Since telemetry services primarily involve data acquisition and delivery, accountability requires measures of the quantity, continuity, and latency of the data delivered.

3.2.1 Telemetry Services Metrics

There are several attributes of telemetry services metrics.

3.2.1.1 Quantity

Quantity is defined as the volume of "acceptable" data units delivered by the service. For telemetry, *data units* are Frames, Packets, and Files. Quantity is measured as the percentage of the total data return expected from the execution of the service instances, over a period of one month, as committed in the schedule. The DSN routinely achieves 95% delivery during the life of mission; however, up to 98% is achievable provided there is sufficient justification and special arrangements are made, e.g. for supporting mission critical events. These values are derived from an assessed probability of unrecoverable data loss based upon "system availability" statistics from the DSN telemetry system. It must also be noted that use of acknowledged Telemetry File service will significantly improve the percentage of original data delivered.

The *quantity* metrics defined above do not take into account the following causes of data loss:

- Insufficient data margin for the space link
- Adverse weather conditions
- Loss of data due to certain spacecraft events or anomalies, (e.g. occultation, spacecraft off-pointing during downlink, tracking mode change, and sequence errors)

Users of any frequency band will experience some outages due to adverse weather conditions. The extent of outages depends strongly on the user's assumptions about weather when configuring their spacecraft, and the application of data management techniques such as CFDP. Users are advised to design their data return strategy to be tolerant of weather caused data delays or gaps. The peak data quantity at S-, X-, and Ka-band is currently believed to result from assuming approximately 98th, 95th, and 90th percentile weather respectively when using long term statistical averages. Thus the user should design the data return strategy such that planned re-transmission of 2%, 5%, or 10% is acceptable. However, since the role of climatic fluctuation is not yet fully understood at Ka-band, some consideration should be given to the possibility that weather will be significantly better or worse than the historical averages. For optimal link utilization at Ka-band users should plan on near real-time data rate adjustments based on weather conditions.

3.2.1.2 Quality

Quality is defined as the "error rate" for the delivered data units over the end-to-end path.

A major contributing factor to telemetry *quality* is the *frame rejection rate*. Telemetry *data units* typically use error-detecting, error-correcting codes such as Reed Solomon, convolutional, turbo, or some combination of these. Table 3.4 gives some sample *frame rejection rates* for variation of block size, coding scheme, and link margin. As the table illustrates, customers must determine the acceptable frame rejection rate for their circumstances, select a coding scheme accordingly, and maintain an adequate link margin in order to ensure the required performance.

Table 3-4. Example Frame Rejection Rates

Frame Rejection Rate	Block Size (frame or packet)	Coding and Link Margin
$< 10^{-6}$	8920 bits	Convolutional (r=1/2, k=7), code concatenated with Reed-Solomon (223/255) block code; @ $E_b/N_0 \geq 1.8$dB
$< 10^{-4}$	8920 bits	Rate = 1/3 turbo code; @ $E_b/N_0 \geq 0.4$dB
$< 10^{-5}$	1784 bits	Rate = 1/6 turbo code; @ $E_b/N_0 \geq 0.4$dB

Another contributing factor to telemetry quality, the undetected error rate introduced by ground equipment, is less than 4×10^{-12}, and can therefore typically be ignored.

Data quality identified in Tables 3.5 - 3.7 assumes sufficient E_b/N_o floor provided for the space return link. The conditions required to meet the telemetry data continuity as described in section 3.2.1.3 are also applicable to the telemetry data quality.

3.2.1.3 Continuity

Continuity is defined as the number of gaps in the set of data units delivered to a customer during a scheduled pass. A gap is defined as the loss of one or more consecutive data units. Continuity is distinguished from quality in that the former counts the number of gaps (holes) in the data set during a scheduled pass, while the latter measures the percentage of the total number of data units returned to a customer during the same scheduled pass.

Data units are Frames or Packets depending upon the subscribed service type.

For a frame length of approximately 8920 bits, the DSN routinely provides a gap rate less than or equal to 8 gaps in 10,000 frames, for a frame length of 8920 bits provided:

- The E_b/N_0 is sufficient for a Frame Rejection Rate $\leq 1 \times 10^{-5}$ at all times during the pass.
- There are no spacecraft anomalies throughout the pass.
- The telemetry data rate does not change during the pass necessitating reacquisition.
- No RFI events occur during the pass.

Obtaining higher levels of continuity requires special, human-intensive effort on a recurring basis. Potential users are therefore advised to design their mission data return strategy to be tolerant of occasional gaps. A gap-rate of 8/10,000 frames as described above should be expected as the nominal condition.

3.2.1.4 Latency

The definition of *Latency* for telemetry is the delay between a data unit's reception at a specified point and its delivery to another point where it becomes accessible to a customer. For *Telemetry Frame Service, Telemetry Packet Service*, and *Telemetry File Service* the point of reception is the antenna (or antennas) when the corresponding frame(s) of the data unit (frame, packet, or file) are acquired and the point of delivery is the customer's MOS.

Three grades of Quality of Service (QoS) are defined for telemetry, each corresponding to a specific delivery mode:

- Grade-1: On-line Timely – The rate of data delivery keeps up with the rate of ingestion throughout the duration of the incoming data stream. The latency for each data unit is nominally a few seconds or less. Completeness of data delivery is not guaranteed, however completeness greater than or equal 95% for each data stream is typically achieved. Availability of this mode is limited due to resource limitations. Each mission is expected to limit its on-line timely data to no more than 100 kbps at any given downlink time. On-line Timely delivery is not supported for *Telemetry File Service*.
- Grade-2: On-line Complete – Delivery of data units within a data stream may be delayed due to resource constraints (primarily availability of outbound ground communications bandwidth). Latencies for individual data units can range from minutes to hours. Completeness or data delivery for each data stream is guaranteed to be greater than or equal 99.99% at least 99.99% of the time.
- Grade-3: Off-line Complete – Delivery of the entire data stream is delayed. This may be due to provider resource constraints (primarily availability of outbound ground communications bandwidth) or due to other causes (such as the operational strategy of the customer). Data units are staged in a repository as they are acquired, then retrieved and delivered at a later time. Typical latencies for the entire data stream can range from one to twenty-four hours depending on the time of data retrieval by the mission and, in some cases, the availability of the public internet when used. Completeness of data delivery for each data stream greater than or equal 99.99% at least 99.99% of the time can be achieved.

The latencies for the above QoS are also a function of the aggregate data acquisition (capture) rates at the DSN site, i.e., the DSCC. They will vary from time to time.

3.2.1.5 Telemetry Data Acquisition Throughput

Depending on the link performance, coding scheme, modulation method, and other factors, the maximum telemetry acquisition or capture rate supported by the DSN is:

- 6 Mbps (deep space) and 125 Mbps (for near Earth — FY'09 at Canberra, and FY'11 at Goldstone and Madrid) for convolutional encoded data (r=1/2, k=7) concatenated with Reed-Solomon encoding;
- 1.6 Mbps for Turbo encoded data;
- The minimum supported data rate is 10 bps (uncoded).

However, since multiple missions are simultaneously tracked by each DSCC, the achievable telemetry data acquisition throughput for a given mission is constrained by the maximum aggregate data capture rate at the DSCC, which is 13.5 Mbps presently. A consequence, for example, is that the number of missions simultaneously downlinking at higher data rate, e.g. 6 Mbps, over the same DSCC is limited.

3.2.2 Bit Stream Service

The Bit Stream Service provides a series of data units. Each data unit contains a stream of hard symbols or convolutionally decoded bits, in the order received, with an undetermined starting point, and without value-added processing such as frame decoding. Certain metadata is appended (e.g., received time of a certain bit, spacecraft ID, spacecraft bit rate, SNR, etc.).

Bit Stream service is slated for decommissioning and is not available to new customers. The status of the data cannot be derived without further processing, hence the quality cannot be guaranteed.

3.2.3 Telemetry Frame Service

Telemetry Frame Service is available to missions meeting the following criteria:

- A frame structure compliant with the CCSDS Packet Telemetry[9] recommendation or CCSDS Advanced Orbiting Systems (AOS)[10]
- A fixed length frame, where each frame is preceded by a CCSDS compliant synchronization marker.
- The frame bits are pseudo-randomized according to the CCSDS Recommendation for Telemetry Channel Coding
- Each frame contains a CRC checksum

The following output options are available for frame service:

- All Frame service[11], which provides both actual data frames and filler frames;
- Virtual Channel service[12], which provides data frames, i.e., virtual channel data units (VCDUs), within each virtual channel. All data frames within a virtual channel are delivered in order of their acquisition time.

Table 3.5 contains a set of attributes summarizing the functions, performance, and interfaces for the Telemetry Frame Service. Relevant documents to this service are also identified in the table.

Table 3-5. Attributes of the Telemetry Frame Service

Parameter	Value
Frequency Bands Supported	Near-Earth S, X, Ka* Deep space S, X, Ka
G/T @ 45 Degree Elevation in dB (refer to Table 5.1)	S-Band Best Worst 34m BWG 41.3 40.8 34m HEF 40.2 39.6 70m 51.0 50.9 26m 31.9 31.8 X-Band Best Worst 34m BWG 55.5 52.8 34m HEF 54.0 54.0 70m 63.1 62.8 Ka-Band Best Worst 34m BWG 65.7 64.1
Polarizations Supported	RCP LCP RCP/LCP simultaneity at some stations for X-band. Refer to Table 5.1.

[9] Packet Telemetry Services, CCSDS 103.0-B-1, Blue Book, Issue 1, May 1996

[10] CCSDS AOS Space Link Protocol (refer to CCSDS 732.0-B-2)

[11] Space Link Extension Return All Frames Service, CCSDS 911.1, Red Book, Issue 1.7, September 1999

[12] Space Link Extension Return Virtual Channel Frame Service, CCSDS 911.2, Red Book, Issue 1.7, September 1999

Parameter	Value
Modulation Types	BPSK on residual carrier (with or without subcarrier) BPSK on suppressed carrier QPSK, OQPSK (no ranging)
Modulation Formats	NRZ: L, M, S; Bi-phase L or Manchester, M, S
Carrier/Subcarrier Waveform	Residual carrier: sine or square waves
Downlink Data Rate	Maximum: 6 Mbps for deep space 125 Mbps for near Earth* Minimum: 10 bps
Downlink Symbol Rate	Maximum: 26 M symbols/second for deep space 250 M symbols for near Earth* Minimum: 10 symbols/second
Channel Coding	Convolutional codes: (k=7, r=1/2) and (k=15, r=1/6)** Turbo codes: 1/2, 1/3, and 1/4 (1.6 Mbps max) Turbo code: 1/6 (1 Mbps max)
Forward Error Correction Codes	Reed-Solomon (RS) interleave = 1 to 8 Reed-Solomon concatenated with convolutional code Reed-Solomon without convolutional code Turbo code
Data from Spacecraft to the DSN	Transfer frame format conforming to CCSDS TM Space Data Link Protocol (ref. CCSDS 132.0-B-1) VCDUs conforming to CCSDS AOS Space Data Link Protocol (ref. CCSDS 732.0-B-2)
Data from the DSN to MOC	Stream of frames or VCDUs
Data Unit Size (information bits only)	TM frame or VDCU: 8920 bits (nominal), 1760 bits (safing and critical events) 16 kbits (maximum)
Maximum Number Of Virtual Channels Supported	64
Data Retention Period at the DSN	Data retention until custody transfer or for 14 days after acquisition (30 days, but available only to missions with an existing commitment)
Data Delivery Methods from the DSN to the MOC	CCSDS Space Link Extension (SLE) RAF/RCF (ref. CCSDS 911.1-R-1.7 and 911.2-R-1.7) On-line timely On-line complete Off-line
Data Delivery Latency (DSN to MOC)	Engineering telemetry: Typically on-line timely (seconds) and complete (seconds to 5 minutes) Science telemetry: Typically off-line (hours to 24 hours).
Service Operating Mode	Automated
Service Availability	Nominal: 95% Mission critical event: 98%

Parameter	Value
Data Completeness	Nominal: 95% acquired frames Mission critical data: 98%
Data Quality	Frame rejection rate: 10^{-4} to 10^{-5} typical
Time Tagging Accuracy	10-50 microsec in Earth Receive Time (ERT) relative to UTC depending on downlink data rate and frame length
Accountability Reporting	SLE RAF/RCF status report Frame accountability report
Ground Communication Interface Methods	Refer to Section 3.8
DSN Interface Specifications	DSN document 810-005; 820-013 0163-Telecomm

* Future new capability, will be available at the end of 2008
** Decommissioned, available only to missions with existing commitment

3.2.4 Telemetry Packet Service

The Packet service extracts packets from frames, i.e., virtual channel data units (VCDUs), and delivers them to the customer's MOS. In essence, it includes the functionality of the lower services, i.e., telemetry frame service and telemetry packet extraction capability. The customer's spacecraft must comply with the CCSDS packet telemetry recommendation[13] in order to use this service. The following output options are available for Packet service:

- Extracted packets are ordered by Earth received time (ERT)
- Extracted packets are ordered by a combination of user-specified mission parameters (e.g., application identifier, packet generation time, packet sequence number, etc.)

Table 3.6 contains a set of attributes summarizing the functions, performance, and interfaces for the Telemetry Packet Service. Relevant documents for this service are also identified in the table.

[13] Packet Telemetry Services, CCSDS 103.0-B-1, Blue Book, Issue 1, May 1996

Table 3-6. Attributes of the Telemetry Packet Service

Parameter	Value
Frequency Bands Supported	Near-Earth S, X, Ka* Deep space S, X, Ka
G/T @ 45 Degree Elevation in dB (refer to Table 5.1)	S-Band Best Worst 34m BWG 41.3 40.8 34m HEF 40.2 39.6 70m 51.0 50.9 26m 31.9 31.8 X-Band Best Worst 34m BWG 55.5 52.8 34m HEF 54.0 54.0 70m 63.1 62.8 Ka-Band Best Worst 34m BWG 65.7 64.1
Polarizations Supported	RCP LCP RCP/LCP simultaneity at some stations for X-band. Refer to Table 5.1.
Modulation Types	BPSK on residual carrier (with or without subcarrier) BPSK on suppressed carrier QPSK, OQPSK (no ranging)
Modulation Formats	NRZ: L, M, S; Bi-phase L or Manchester, M, S
Carrier/Subcarrier Waveform	Residual carrier: sine or square waves
Downlink Data Rate	Maximum: 6 Mbps for deep space 125 Mbps for near Earth* Minimum: 10 bps
Downlink Symbol Rate	Maximum: 26 M symbols/second for deep space 250 M symbols for near Earth* Minimum: 10 symbols/second
Channel Coding	Convolutional codes: (k=7, r=1/2) and (k=15, r=1/6)** Turbo codes: 1/2, 1/3, and 1/4 (1.6 Mbps max) Turbo code: 1/6 (1 Mbps max)
Forward Error Correction Codes	Reed-Solomon (RS) interleave = 1 to 8 Reed-Solomon concatenated with convolutional code Reed-Solomon without convolutional code Turbo code
Data from Spacecraft to DSN	Packets conforming to CCSDS TM Space Packet Protocol (ref. CCSDS 133.0-B-1)

Parameter	Value
Data from DSN to MOC	Stream of packets
Data Unit Size	TM packet: maximum of 30 kbytes plus SFDU header
Maximum Number Of Virtual Channels Supported	64
Data Retention Period at DSN	Data retention until custody transfer or for 14 days after acquisition (30 days, but available only to missions with an existing commitment)
Data Delivery Methods from the DSN to the MOC	Query access to the database, on-line during the pass or off-line after the pass
Data Delivery Latency (DSN to MOC)	Engineering telemetry: Typically on-line timely (seconds) and complete (seconds to 5 minutes) Science telemetry: Typically off-line (hours to 24 hours).
Service Operating Mode	Automated
Service Availability	Nominal: 95% Mission critical event: 98%
Data Completeness	Nominal: 95% acquired frames Mission critical data: 98%
Data Quality	Frame rejection rate: 10^{-4} to 10^{-5} (typical)
Time Tagging Accuracy	10-50 microsec in Earth Receive Time (ERT) relative to UTC depending on downlink data rate and frame length
Accountability Reporting	Gap report
Ground Communication Interface Methods	Refer to Section 3.8
DSN Interface Specifications	DSN document 810-005; 820-013 0172-Telecomm

* Future new capability, will be available at the end of 2008
** Decommissioned, available only to missions with existing commitment

3.2.5 Telemetry File Service

The Telemetry File service recovers files transmitted according to the CCSDS File Delivery Protocol (CFDP)[14]. The service extracts Protocol Data Units (PDU's) from packets and re-assembles the PDU's into files. The resulting files are then made available to the customer's MOS, along with meta-data describing the file content (to the extent this is provided in the original PDU's) and the transaction. This service also supports transfer of directory listings, file transmission status, and other messages as specified in the protocol. The Telemetry File service can operate in either of two basic modes:

- Unacknowledged mode – In this mode, missing PDU's or other uncorrected errors in transmission are not reported to the spacecraft. This mode thus requires neither use of an uplink nor interactive response from the spacecraft. However, missed data will not be automatically retransmitted. This is referred to in the CCSDS specification as "unreliable transfer".
- Acknowledged mode – This mode guarantees complete file transfer within the parameters established for the protocol. The DSN will automatically notify the MOS if file segments or ancillary data are not

[14] CCSDS File Delivery Protocol (CFDP), CCSDS 727.0-B-2, Blue Book, October 2002

successfully received (i.e., PDU's are missing or malformed). The DSN can also automatically respond to the spacecraft with acknowledgement or non-acknowledgement PDU's. The spacecraft can then retransmit the missed items, and the DSN will combine them with the portions that were previously received. Acknowledged mode requires use of an uplink and that the spacecraft cooperate in accord with the CFDP specification. This is referred to in the CCSDS specification as "reliable transfer".

CFDP is a content-independent protocol, which requires no knowledge about the content or structure of a transferred file. The time needed to deliver a final, complete file via the CFDP is a function of the file size, data rate, and round-trip-light-time effect (this is particularly significant in the case of the acknowledged mode).

Table 3.7 contains a set of attributes summarizing the functions, performance, and interfaces for the Telemetry File Service. Relevant documents for this service are also identified in the table.

Table 3-7. Attributes of the Telemetry File Service

Parameter	Value
Frequency Bands Supported	Near-Earth S, X, Ka* Deep space S, X, Ka
G/T @ 45 Degree Elevation in dB (refer to Table 5.1)	S-Band Best Worst 34m BWG 41.3 40.8 34m HEF 40.2 39.6 70m 51.0 50.9 26m 31.9 31.8 X-Band Best Worst 34m BWG 55.5 52.8 34m HEF 54.0 54.0 70m 63.1 62.8 Ka-Band Best Worst 34m BWG 65.7 64.1
Polarizations Supported	RCP LCP RCP/LCP simultaneity at some stations for X-band. Ref. to Table 5.1.
Modulation Types	BPSK on residual carrier (with or without subcarrier) BPSK on suppressed carrier QPSK, OQPSK (no ranging)
Modulation Formats	NRZ: L, M, S; Bi-phase L or Manchester, M, S
Carrier/Subcarrier Waveform	Residual carrier: sine or square waves
Downlink Data Rate	Maximum: 6 Mbps for deep space 125 Mbps for near Earth* Minimum: 10 bps

Parameter	Value
Downlink Symbol Rate	Maximum: 26 M symbols/second for deep space 250 M symbols for near Earth* Minimum: 10 symbols/second
Channel Coding	Convolutional codes: (k=7, r=1/2) and (k=15, r=1/6)** Turbo codes: 1/2, 1/3, and 1/4 (1.6 Mbps max) Turbo code: 1/6 (1 Mbps max)
Forward Error Correction Codes	Reed-Solomon (RS) interleave = 1 to 8 Reed-Solomon concatenated with convolutional code Reed-Solomon without convolutional code Turbo code
Data from Spacecraft to DSN	Files per CCSDS File Delivery Protocol (CFDP) standard (ref. CCSDS 727.0-B-2)
Data from DSN to MOC	Files
Data Unit Size	Maximum PDU size: 30 kbytes, Maximum file size: 4Gbytes
Maximum Number Of Virtual Channels Supported	64
Data Retention Period at DSN	Data retention until custody transfer or for 14 days after acquisition (30 days, but available only to missions with an existing commitment)
Data Delivery Methods from the DSN to the MOC	File transfer on-line during the pass or off-line after the pass
Data Delivery Latency (DSN to MOC)	Engineering telemetry: Typically seconds to 5 minutes Science telemetry: Typically off-line (hours to 24 hours).
Service Operating Mode	Automated
Service Availability	Nominal: 95% Mission critical event: 98%
Data Completeness	99.99% for acknowledged service mode (guaranteed delivery)
Data Quality	Frame rejection rate: 10^{-4} to 10^{-5} (typical)
Time Tagging Accuracy	10-50 microsec in Earth Receive Time (ERT) relative to UTC depending on downlink data rate and frame length
Accountability Reporting	Radiation log, event report, and CFDP transaction log
Ground Communication Interface Methods	Refer to Section 3.8
DSN Interface Specifications	DSN document 810-005; 820-013 0188-Telecomm

* Future new capability, will be available at the end of 2008

** Decommissioned, available only to missions with existing commitment

3.2.6 Beacon Tone Service

The DSN provides the Beacon Tone Service for the flight project MOS to monitor the high-level state of the spacecraft according to the beacon tones generated and transmitted by the spacecraft. The DSN will be capable of acquiring and detecting the 4-tone Beacon Monitoring signals at SNRs down to 5 dB-Hz, with detection times up to 1000 seconds, on the 70m, 34m stations. The detected tone will be forwarded to the project MOS as a message[15]. However, the interpretation of the detected tone is the responsibility of the MOS.

There are some missions, which have a long ion-powered cruise and/or require frequent visibility during periods when the downlink signals drops below threshold for normal telemetry via LGA while on thrust attitude (for example, below a Pt/No of about 18 dB-Hz). In these scenarios, the Beacon Tone Service offers a useful mechanism for the MOS to gain some minimum knowledge about the health and safety of its spacecraft.

3.3 Tracking Services

Tracking Services provide radio metric observables from which the position and velocity of the customer's spacecraft can be derived. Two complementary types of service are available – Validated Radio Metric Data service and Delta-DOR service. The third service, the Raw Radio Metric Measurements Service, is no longer available to new customers.

Table 3.8 contains a set of attributes summarizing the functions, performance, and interfaces for Tracking Services. Relevant documents for these services are also identified in the table.

Table 3-8. Attributes of all Tracking Services

Parameter	Value
Frequency Bands Supported	Uplink: S, X Downlink: S, X, Ka (S and X for both near Earth and deep space bands; Ka for deep space band only)
Frequency Turnaround Ratio (Uplink/Downlink)	S/S: 240/221 S/X: 880/221 X/X: 880/749 X/Ka: 749/3328, 749/3360
Tracking Data Types	Range, Doppler, Delta-DOR. Angle (limited to initial acquisition during LEOP and routine tracking via 26m subnet)
Tracking Modes	Coherent Non-Coherent
Doppler Accuracy (1σ Error)	S-Uplink: 0.2 mm/s, 60s Compression X-Uplink: 0.05 mm/s, 60s Compression Ka Uplink: 0.05 mm/s, 60s Compression
Doppler Measurement Rate	0.1 second

[15] Deep Space Network / Detailed Interface Design, Document No. 820-013, 0162-Telecomm, “Beacon Telemetry SFDU Interface”. July 2004.

Parameter	Value
Ranging Type	Sequential Ranging
Range Accuracy (1σ Error)	1 meter
D-DOR Accuracy (1σ Error)	S-Band: 37.6 nrad (0.3 m) X-Band: 2.5 nrad each for systematic and random errors (0.04 m) Ka-Band: 2.5 nrad each for systematic and random errors (0.04 m)
Downlink Carrier Level	Residual: 10 dB Loop SNR minimum Suppressed: 17 dB Loop SNR minimum
Range Power Level	+50 to -10 dB Hz (P_r/No)
D-DOR Tone Power Level	18 dB Hz (P_T/No) minimum
Data Availability	Doppler/Range: 95% Non-Critical Support 98% Critical Support Delta-DOR: 90% Non-Critical Support 95% Critical Support
Data Latency	Doppler/Range: 5 minutes Delta-DOR: 24 hours
Data Modes (DSN to MOC)	Stream data mode File data mode
Delivery Modes (DSN to MOC)	On-line; Off-line
Ground Communication Interface Methods	Refer to Section 3.8
DSN Interface Specifications	DSN document 810-005; 820-013 TRK-2-34 and TRK-2-18*

* Decommissioned, available only to missions with existing commitment

3.3.1 Raw Radio Metric Measurement Service

This service provides radio metric observables based on measurement of phase and light time delay of the modulated RF signal acquired by the tracking stations. The data are not validated, except for a limited number of internal data validity flags, e.g., signal in lock, signal-to-noise ratio. This service is only applicable to radiometric data acquired from 26m stations conforming to the DSN specification of TRK-2-20[16].

Along with the 26m subnet, Raw Radio Metric Measurement service is slated for decommissioning and is not available to new customers. All radio metric measurements are also available as validated data via the Validated Radio Metric Data service. It is recommended that customers utilize the latter service.

3.3.2 Validated Radio Metric Data Service

The Validated Radio Metric Data Service includes validation and correction of erroneous configuration and associated status data, analysis of radio metric data including validation against the Satellite Ephemeris (P-file) and the Planetary Ephemeris (PE-file), retrieval of missing data, and delivery of re-

[16] Deep Space Network / Detailed Interface Design, Document No. 820-013, TRK-2-20, "DSN Tracking System Universal Tracing Data Interface". October 1994.

conditioned data to navigation. Data which cannot be validated may be delivered to the customer, but are identified as such. All Doppler and ranging data are validated, and all data are delivered in the same DSN format, TRK-2-34[17] and TRK-2-18[18].

3.3.2.1 Doppler Data Performance

Doppler data are the measure of the cumulative number of cycles of a spacecraft's carrier frequency received during a user specified count interval. The exact precision to which these measurements can be made is a function of received signal strength and station electronics, but is a small fraction of a cycle. In order to acquire Doppler data, the user must provide a reference trajectory, and information concerning the spacecraft's RF system to DSN to allow for the generation of pointing and frequency predictions.

The user specified count interval can vary from 0.1 sec to 60 minutes, with typical count times of 1 second to 5 minutes. The average rate-of-change of the cycle count over the count interval expresses a measurement of the average velocity of the spacecraft in the line between the antenna and the spacecraft. The accuracy of Doppler data is quoted in terms of how accurate this velocity measurement is over a 60 second count. The accuracy of data improves as the square root of the count interval.

3.3.2.2 Non-coherent Doppler Data

Non-coherent data (also known as one-way data) is data received from a spacecraft where the downlink carrier frequency is not based on an uplink signal. The ability of the tracking station to measure the phase of the received signal is the same for non-coherent versus coherent data types, however the uncertainty in the value of the reference frequency used to generate the carrier is generally the dominant error source.

3.3.2.3 Coherent Doppler Data

Coherent Doppler data is that received from a spacecraft where the reference frequency of the received carrier signal was based on a transmitted uplink signal from the Earth. This is commonly known as two-way data, when the receiving and transmitting ground stations are the same, and three-way data, when the transmitting and receiving stations are different. Since the frequency of the original source signal is known, this error source does not affect data accuracy. The accuracy of this data is a function primarily of the carrier frequency, but is affected by transmission media effects.

S-band: S-band (2.2 GHz) data is available from 26m, 70m, and some 34m antennas. The one-sigma accuracy of S-band data is approximately 0.2 mm/s for a 60 second count interval after being calibrated for transmission media effects. The dominant systematic error which can affect S-band tracking data is ionospheric transmission delays. When the spacecraft is located angularly close to the Sun, with Sun-Probe-Earth (SPE) angles of less than 10 degrees, degradation of the data accuracy will occur. S-band data is generally unusable for SPE angles less than 5 degrees.

X-band: X-band (8.4 GHz) data is available from 34m and 70m antennas. X-band data provides substantially better accuracy than S-band. The one-sigma accuracy of a 60 second X-band Doppler measurement is approximately 0.05 mm/s. X-band data is less sensitive to ionospheric media delays but more sensitive to weather effects. X-band data is subject to degradation at SPE angles of less than 5 degrees, but is still usable with accuracies of 1 to 5 mm/s at SPE angles of 1 degree.

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[17] Deep Space Network / Detailed Interface Design, Document No. 820-013, TRK-2-34, "DSN Tracking System, Data Archival Format", Rev. I. September 2006.

[18] Deep Space Network / Detailed Interface Design, Document No. 820-013, TRK-2-18, "Tracking System Interfaces Orbit Data File Interface", Rev D, December 2006

Ka-band: Doppler accuracy at Ka-band (32 GHz) is mostly affected by the SPE angle, and for X-band uplink/Ka-band downlink mode the one sigma accuracy is near that as described in X-band uplink/X-band downlink.

The level of errors stated above is based on the assumption of the minimum of 15 dB uplink carrier loop signal-to-noise ratio, and 10 dB downlink carrier loop signal-to-noise ratio for residual carrier tracking (or 17 dB for suppressed carrier tracking).

3.3.2.4 Ranging Data Performance

Ranging data measures the time that it takes a series of signals superimposed upon the uplink carrier frequency to reach the spacecraft, be retransmitted, and then received at an Earth station (round-trip-light-time, RTLT). As such, all DSN ranging systems are intrinsically coherent.

The user of ranging data service must define two of three required parameters: the desired accuracy, the desired range measurement ambiguity, and the maximum observation time. These along with the knowledge of the received ranging power-to-noise ratio will allow for the configuration of the ranging system.

3.3.2.4.1 Sequential Ranging

The 26m, 34m, and 70m subnets utilize a sequential ranging technique. This technique can provide measurements of the range to the spacecraft to 1 meter accuracy for all bands. Note that ranging error is conditioned on range configuration setting.

The sequential ranging technique modulates a series of codes upon the radio signal to the spacecraft. The first of these, the "clock code," defines the resolution or accuracy that the ranging measurement will have. However, the observation from the clock code is ambiguous as it only identifies the fractional part of the clock code period comprising the RTLT, there are an unknown additional integer number of clock periods composing the RTLT. The DSN then sequentially modulates a decreasing series of lower frequency codes upon the signal in order to resolve the ambiguity in the range measurement, by increasing the period of the ranging code. The maximum range ambiguity possible in the DSN is approximately 152,000 km, however ambiguities of 1,190 km and 2,380 km are more commonly used.

The accuracy of a ranging observation is a function of the received power-to-noise ratio in the ranging signal. Greater accuracy can be achieved by observing the "clock code" signal for a longer period of time. For lower power-to-noise ratios it also takes longer to resolve each of the ambiguity resolution codes. Consequently, for a given power-to-noise ratio, a desired accuracy and a desired ambiguity will result in a required observation time. For practical purposes the maximum value for this observation time is 30 minutes. If the desired accuracy and desired ambiguity result in a required observation time greater than 30 minutes, either a change in the ambiguity or the accuracy will be required. A more detailed description is provided in the DSN Telecommunications Link Design Handbook[19].

3.3.2.4.2 26m Tone Ranging

In addition to the sequential technique, the 26m subnet also supports a second order ranging system which is a hybrid system combining a harmonic side tone ranging system with a binary encoded ambiguity resolving code. This system operates only at S-band and provides a measurement accuracy varying from 1 to 10 meters for Earth orbiting spacecraft. The ambiguity of the measurement is 644,000 km. A more detailed description is provided in the DSN Telecommunications Link Design Handbook[20].

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[19] Module 203 of the DSN Telecommunications Link Design Handbook, Document No. 810-005, Rev. E, Jet Propulsion Laboratory, Pasadena, California

[20] Module 204 of the DSN Telecommunications Link Design Handbook, Document No. 810-005810-005, Rev. E, Jet Propulsion Laboratory, Pasadena, California

This tracking data type is no longer available to new customers.

3.3.2.5 Grades of Service – Latency and Quality

There are, in effect, two grades of service for the Validated Radio Metric Data Service:

- Grade 1 corresponds to the output data that has passed through the automated validation process which ensures that configuration meta-data is complete and consistent to some unspecified level of confidence. Grade 1 may be delivered via a real-time interface (with latency less than or equal to 5 minutes 99% of the time) or via a file-drop interface (with longer latency). Grade 1 is available in TRK-2-34 format.
- Grade 2 corresponds to the output data that has additionally passed through the manual validation process, which utilizes short-arc (about 1 tracking pass) fits to identify anomalous data. Delivery is via a file-drop interface similar to that used for Grade 1. Grade 2 is available in either TRK-2-34 or TRK-2-18 file formats. Latency for Grade 2 is nominally 24 hours, with an option to negotiate for 30 to 60 minute turnaround for mission critical events.

3.3.3 Delta-DOR Service

The delta-differential one-way ranging (delta-DOR) technique provides an observation of the plane-of-the-sky position of a spacecraft, using signals received simultaneously at two or more antennas. In this technique, a spacecraft emits two or more side tones separated from its carrier by a large frequency offset, typically tens of MHz or more. Each of these tones are recorded at two stations simultaneously. Nearly contemporaneously, a quasar is observed with the same pair of stations (this may be done in the pattern quasar-spacecraft-quasar, spacecraft-quasar-spacecraft, quasar-spacecraft_1-spacecraft_2-quasar, etc.). The signals are analyzed afterwards to calculate the delta-DOR observable.

Due to the need to model the geometry of the observation of each radio source, a separate time delay observable is reported for each source and for each measurement time. The inter-station clock offset is also provided to the customer. The data are delivered in the DSN format, 820-013 TRK-2-34[21] (with a provision of temporary retention to the legacy format of TRK-2-18). Quality assessments are also provided with the data, based on a large number of quality indicators both taken with the data and inferred during signal processing.

To receive validated delta-DOR data, the subscriber negotiates the times of spacecraft and quasar observations, and requests the service. A number of factors must be considered concerning the time and geometry of the session in order to obtain successful results; therefore DSN provides assistance in the scheduling. The subscriber then arranges that the spacecraft is on Earth point, with DOR tones turned on at the planned time of observation. Important side-effects of the delta-DOR session are:

- Spacecraft telemetry may be degraded when the DOR tones are on, *and*
- All other radio services (telemetry, command, radio metrics) will *not* be available during the quasar observations, because the ground antennas must be pointed away from the spacecraft.

3.3.3.1 Delta DOR Data Performance

Assuming sufficient signal detection, the delta-DOR measurements are expected to have the following accuracy:

- 0.3 m at S-band, assuming a minimum 7 MHz DOR tones separation

[21] Deep Space Network / Detailed Interface Design, Document No. 820-013, TRK-2-34, "DSN Tracking System, Data Archival Format", Rev. I. September 2006.

- 0.04 m (or 2.5 nrad for each random and systematic errors) at X-band, assuming a minimum 20 MHz DOR tones separation
- 0.04 m (or 2.5 nrad for each random and systematic errors) at Ka-band, assuming a minimum 80 MHz DOR tones separation

The above values further assume a condition of sufficient signal detection and minimal interference, e.g., a spacecraft transmitted tone separation of at least 38 MHz, a received tone power signal-to-noise ratio of 18 dB Hz or greater, for spacecraft/Sun separation angle of at least 20 degrees, for a spacecraft trajectory within 10 deg of the ecliptic plane, and for spacecraft geocentric declination angles above -15 deg.

3.4 Calibration and Modeling Services

This service provides the subscriber with calibrations needed to process tracking data to the fullest accuracy possible. Calibrations specifically related to the data acquisition hardware are automatically delivered to subscribers of those data. These calibrations deal with systematic error sources, which affect the accuracy of tracking observables.

3.4.1 Platform Calibration Service

Platform Calibration Service provides Earth orientation parameters (EOP) data referenced to the terrestrial and celestial frames.

In order to process DSN radio metric data, the subscriber must know the inertial position of the station at the time of the measurement. Although the locations of DSN antennas are known to within centimeters and the baselines between them to millimeters, the variations in polar motion and the rotation rate of the Earth can move the inertial position by much larger amounts than this. The terrestrial frame tie data provides a temporal model for the orientation of the Earth's pole and the spin rate based upon VLBI observations and tracking of GPS satellites. This data provides the subscriber with an instantaneous knowledge of the inertial position of a crust fixed location on the Earth's equator to 30 cm. A posterior knowledge on the order of 5 cm (1-sigma) is available after 14 days.

For Earth orientation parameters (EOP), the accuracy of the polar motion parameters (PMX and PMY) is within 5 cm (1-sigma) and the spin parameter (UT1) is within 30 cm (1-sigma) in real-time.

A quasi-inertial celestial reference frame in International Earth Rotation and Reference Systems (IERS) format referenced to epoch J2000 is provided with an accuracy to better than 1 nrad (1-sigma) with a measured stability of better than 0.1 nrad/year (1-sigma).

Typically, platform calibration data, i.e., EOP data and reference frame tie data, are delivered twice a month (refer to DSN document 820-013, TRK-2-21, "DSN Tracking System Earth Orientation Parameters Data Interface" for more details).

3.4.2 Media Calibration Service

The transmission media through which the signals pass affects radio signals. The most significant of these are the Earth's troposphere and ionosphere. In order to achieve the data accuracies discussed in the previous sections on data services, it is necessary to calculate adjustments for the delays due to these. The media calibration models are based upon tracking of GPS satellites at two frequencies. The format of these calibrations is a history of zenith delay over a pass and a mapping function to map them to the appropriate altitude.

Calibrations for the zenith tropospheric delay are delivered to an accuracy of 1 cm (1-sigma) for all times through the end of the Universal Time (UT) day before the delivery and 2cm (1-sigma) accuracy for subsequent times that are covered on the UT day of the delivery. The Calibrations for ionospheric delay are delivered with an accuracy of 5 Total Electron Content (TEC) at the spacecraft line-of-sight, averaged over a standard Doppler tracking pass, which corresponds approximately to 0.2 cm at Ka-band, 3 cm at X-band, and 38 cm at S-band.

Typically, all media calibration data are delivered twice a week to customers (refer to DSN document 820-013, TRK-2-23, “Media Calibration Interface” for more details).

3.5 Radio Science Services

DSN Radio Science Services are provided to scientists to enable them to use the Deep Space Network for direct scientific observations. The services deliver measurements of the spacecraft downlink signal from either open-loop or closed-loop receivers. Data from the open-loop receiver are digital recordings of the baseband signal derived from the received spacecraft signal at S-, X-, or Ka-band (refer to DSN document 820-013, 0159-Science, “Radio Science Receiver Standard Formatted Data Unit” for more details). Closed-loop receiver data are measurements of the Doppler frequency and spacecraft range (see the Tracking Service description for more details).

Key performance characteristics of radio science services in metrics such as frequency stability, phase noise, and amplitude stability, are described in the DSN Telecommunication Link Design Handbook[22].

The Radio Science Services are further divided into two types of service based on the level of operational activities involved.

3.5.1 Experiment Access Service

Experiment Access Service is aimed at users with expertise in the DSN science capabilities and provides them with access to the equipment and technical assistance, including operations support and scientific collaboration when appropriate, to perform their experiments. In some cases access can be via remote operations terminals, rather than onsite.

3.5.2 Data Acquisition Service

Data Acquisition Service provides raw measurements and ancillary data from observations. DSN provides scheduling, experiment design, instrument operations, and data delivery based on agreements negotiated prior to the observations. Data Acquisition service subsumes Experiment Access service--separate subscription to the latter is not required.

3.6 Radio Astronomy/VLBI Services

The Radio Astronomy/VLBI Services uses the high gain, low system noise temperature antennas of the DSN to make observations of RF emitting astronomical sources. The Radio Astronomy capabilities are intimately related to the DSN's R&D programs in science and technology. For observations within standard DSN communications bands, users are provided conditioned IF signals. These IF signals can then become input to either DSN-supplied special purpose receiving and data acquisition equipment being used for R&D or user supplied equipment. For observations outside the standard communications bands, investigators can use special purpose R&D microwave and receiving equipment, when available.

Radio Astronomers using DSN antennas as part of a network in Very Long Baseline Interferometry (VLBI) observations receive digitized and formatted samples of an open-loop signal on VLBA (Very Long Baseline Array) compatible tapes. VLBI observations are supported using a standard Mark IV VLBI data acquisition system. Correlation of VLBI data from up to four antennas is also available.

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[22] Module 209, Open-Loop Radio Science in DSN Telecommunications Link Design Handbook, Document No. 810-005, Rev. E, Jet Propulsion Laboratory, Pasadena, California

The Radio Astronomy/VLBI Services can be categorized into three types of services.

3.6.1 Signal Capturing Service

The Signal Capture Service provides antenna pointing, radio frequency output, and/or output at an intermediate frequency (down-converted from RF) for observations of natural radio emitters. R&D equipment, external to this service, is used to complete signal processing and data acquisition. Amplification and down-conversion of signals is available at "standard" DSN communications frequencies defined in the DSN Telecommunication Link Design Handbook[23]. Use of special-purpose R&D equipment for observations at other frequencies and bands may be negotiated through the DSN Advanced Tracking & Observational Techniques (ATOT) office.

3.6.2 VLBI Data Acquisition Service

The VLBI Data Acquisition Service includes signal capture and utilizes the Mark IV VLBI Field System for data acquisition and recording. The Mark IV/Mark V system, including the Mark IV data format, is a standard used at radio observatories throughout the world and is described in the reference document listed above in "applicable documents." This service includes delivery of data to a user-designated correlator.

3.6.3 VLBI Data Correlation Service

The VLBI Data Correlation service provides the capability to cross correlate up to 2 data streams in the Mark IV format on tape or Mark-5 disk. By the end of 2008, it is expected that only Mark-5 disks will be supported.

Key performance characteristics of VLBI services in terms of accuracy of VLBI measurements are described in the DSN Telecommunication Link Design Handbook[24].

3.7 Radar Science Services

The DSN Radar Science Services are provided to scientists to enable them to use the Deep Space Network for direct scientific observations. The Radar Service provides observations from the Goldstone Solar System Radar (GSSR), a dual wavelength (3.5 cm and 12.5 cm), multi-aperture, high power, simultaneous dual polarization reception (RCP and LCP), radar. The GSSR can be operated in continuous wave or binary phase coded modes. Interferometric observations using up to four DSN receiving antennas are possible as are bi-static observations with the radar at the Arecibo Observatory or the Greenbank Telescope.

It is the only fully steerable planetary radar system in the world. This characteristic makes it extremely valuable for observations of Near-Earth asteroids and comets which typically encounter the Earth at a wide variety of declinations.

The modes of operation of the GSSR fall into three broad categories, all at both 3.5-cm and 12.5-cm:

- Continuous Wave Modes – There are three CW modes, each with different hardware subsystems (normally both circular polarizations are received in CW observations):
    - Narrow bandwidth – This mode is offered for targets whose received bandwidth spreading is no more than 40 kHz.

[23] DSN Telecommunications Link Design Handbook, Document No. 810-005, Rev. E, Jet Propulsion Laboratory, Pasadena, California

[24] Module 210, Narrow Channel Bandwidth VLBI and Module 211, Wide Channel Bandwidth VLBI, of DSN Telecommunications Link Design Handbook, Document No. 810-005, Rev. E, Jet Propulsion Laboratory, Pasadena, California

  - Medium bandwidth – This mode is offered for targets whose received bandwidth spreading is no more than 8 MHz.
  - Wide bandwidth – This mode is offered for targets whose received bandwidth spreading is no more than 40 MHz.
- Binary Phase Coded (BPC) Modes – The possible modes provided are divided by received polarization diversity and the number of stations receiving. The transmitter subsystem can supply either right or left circular polarization signals in the BPC mode. The receivers at DSS-14 and DSS-13 can be configured for both or either circular polarization. DSS-15 and DSS-25 can only receive a single polarization, with RCP or LCP at the experimenter's choice.
- Interferometric Observations Modes – The GSSR can utilize the following baselines at the Goldstone Deep Space Communications Complex: DSS-14 to DSS-13, DSS-13 to DSS-25, DSS-13 to DSS-15, DSS-15 to DSS-25, and DSS-14 to DSS-25. The DSS-14 to DSS-15 baseline is too short for any practical application. In addition, the GSSR can transmit a CW signal designed to be used for direct imaging in both polarizations at the Very Large Array (VLA) of the National Radio Astronomy Observatories (NRAO, Socorro, NM) and the Very Large Baseline Array (data processing at the NRAO correlator in this case only, also in Socorro).

The Radar Science Services are further divided into two types of service based on the level of operational activities involved.

3.7.1 Experiment Access Service

The first level of service is aimed at users with expertise in the DSN science capabilities and provides them with access to the equipment and technical assistance, including operations support and scientific collaboration when appropriate, to perform their experiments. In some cases access can be via remote operations terminals, rather than onsite.

3.7.2 Data Acquisition Service

The second level of service provides raw measurements and ancillary data from observations. DSN provides scheduling, experiment design, instrument operations, and data delivery based on agreements negotiated prior to the observations. Data Acquisition service subsumes Experiment Access service. Separate subscription to the latter is not required.

3.8 Ground Communications Interface

The Ground Communications Interface is not a service. It is an underlying function of the various DSN services in that it must be performed by both the DSN, as the service provider, and the MOC, as the service user, so that service data, e.g. telemetry, command, and tracking data, can be transferred via a reliable and secure communications interface between a DSN site or the DSN NOCC and the Project MOS. This function encompasses the ground communication interface at the physical, data link, and network layers. To provide the interface, four different approaches are available:

a) Using the NASA Integrated Service Network (NISN),

b) Using the dedicated communications link,

c) Using the Public Internet via a Virtual Private Network (VPN),

d) Using the JPL Flight Operations Network.

In addition, any combination of (a), (b), and (c) above may be applied.

The applicability to mission users, cost attribution, and roles and responsibilities pertaining to the four approaches are summarized in Table 3.9.

Table 3-9. Summary of the Approaches to Ground Communications Interface

	Applicable Mission Users Base	Cost Attribution	DSN's Role	Mission's Role
a) NISN	NASA missions only MOC with physical access to NISN backbone infrastructure	DSN for the NISN services including terminating equipment at both ends (MOC and DSN) Mission users for the router at the MOC.	Broker for NISN services Plan with NISN to provide and test the communications capability. Provide Flight Op Network security.	Support NISN to test the communications capability.
b) Dedicated Communications Link	NASA or non-NASA missions MOC at any geographical location	Mission users for communications line, terminating equipment at both ends (MOC and DSN/NISN), and the router at the MOC DSN for router at the DSN side	Support the mission to integrate & test the communications capability Provide Flight Op Network security	Plan, procure, and install the communications line Integrate & test the end-to-end communications capability Maintain integrity of the communications path during operations
c) Public Internet (VPN)	NASA or non-NASA missions MOC at any geographical location	Mission users for Internet access at MOC; DSN for Internet access and security.	Support the mission to integrate & test the communications capability Provide Flight Op Network security	Plan and test the communications capability Maintain integrity of the communications path during operations
d) JPL Flight Operation Network	NASA JPL missions only MOC physically located at JPL	DSN for the Flight Operations Network ethernet backbone (DSN portion) and the connections of DSN equipment to the Ethernet Mission users / AMMOS for their connections to the Ethernet backbone	Total responsibility for the Flight Op Network (DSN portion) Provide Flight Op Network security Maintain Integrity of the communications path during operations	Support the integration & test of the interface between MOC and Flight Operations Network

3.9 Service Management

Data services provided by the DSN are requested and controlled via a unified service management function. Service management by itself is not a service. It is a distributed function with elements residing at the NOCC as well as at each of the DSCC's. It includes:

- Allocation and scheduling of space communication resources and assets during the service commitment and scheduling phases.
- Configuring, monitoring, and controlling the DSN assets during the service provision phase (i.e., before, during, and after a pass).
- Reporting of service execution results, including performance.

Customers interact with service management by one of the following

- Generating a predicted spacecraft trajectory via an interface conforming to the CCSDS Orbit Ephemeris Message standard[25], or the Spacecraft-Planet Kernel (SPK) format[26] as defined in the 820-013, 0168-Service_Mgmt.
- Making schedule requests via an interface conforming to the Schedule Request, 820-013, OPS-6-12[27] or its variations.
- Providing spacecraft telecommunication events and link characteristics via interface conforming to the Keyword Files, OPS-6-13 document[28] or its variations.

The DSN is continuing its evolution towards the goal of a single, integrated process for long-range resource allocation, mid-range scheduling, near-real-time scheduling, and real-time configuration and control, with a common "service request" interface.

[25] Orbit Data Messages, CCSDS Blue Book, 502.0-B-1, September 2004

[26] Deep Space Network / Detailed Interface Design, Document No. 820-013, 0168-Service_Mgmt, "DSMS Web Portal Services", May 2006

[27] Deep Space Network / Detailed Interface Design, Document No. 820-013, OPS-6-12, "Remote Mission Operations Centers and 26-Meter Project/User Interface to the DSN Schedule and Sequence of Events Generation", Jun 2003

[28] Deep Space Network / Detailed Interface Design, Document No. 820-013, OPS-6-13, "Flight Project Interface to the DSN for Sequence of Events Generation", Rev D, Apr 2005

Section 4
Engineering Support

This section describes the engineering support activities offered by the DSN. Engineering support activities comprise participation in mission activities by DSN engineering personnel. Support can be provided during any phase of the mission life-cycle.

4.1 Systems Engineering Support

DSN engineering personnel can provide systems engineering support to missions to assist them in defining their end-to-end information system and mission operations system architecture, defining operations concepts, identifying system solutions, and defining interfaces.

4.2 Advance Mission Planning Support

DSN engineering personnel can assist future mission planners in identifying and verifying their requirements for DSN services, proposing and assessing telecommunication designs to ensure compatibility with the DSN, identifying optimal tracking and data acquisition approaches, and planning for mission system integration and test (I&T) and mission operations.

4.3 Emergency Mission Operations Center Support

For a customer subscribing to the use of the Emergency Control Center (ECC), engineering support will be provided to the contingency flight team in getting the data system, e.g., work stations and network connections, into an operable state. (Note: The ECC is a scaled-down version of the mission operations center. One of its purposes is to allow the mission to resume limited operations in the event of a natural disaster or other catastrophic event which disables certain facilities of a mission operations center.)

4.4 RF Compatibility Test Support

Before launch, RF compatibility test equipment will be available for use in validating the RF interface compatibility between the spacecraft and the DSN, signal processing for telemetry, command, and tracking functions, and some data flow compatibility. The compatibility test equipment emulates the data modulation/demodulation capabilities via an RF link hardline to the customer's spacecraft.

Additional details about this support are addressed in section 6.3.1.1.8 "Compatibility Testing DSN Costing".

4.5 Mission System Test Support

The DSN assets will be available for supporting the various system tests conducted by the flight projects. Examples of these tests are spacecraft system tests (ATLO system tests) and end-to-end system tests. Since the objective of the system tests typically goes beyond the verification of the point-to-point RF capabilities, some operational DSN assets in addition to those test facilities used for RF compatibility tests may be required.

4.6 Spectrum and Frequency Management Support

The DSN Program Office is responsible to NASA and to the international Space Frequency Coordination Group (SFCG) for managing deep space spectrum and frequency resources. In that capacity, DSN engineering personnel help the customers with frequency selection, coordinate the selected frequencies with other users of the spectrum, ensure compliance with applicable national and international spectrum rules, perform conflict analysis, make interference avoidance/mitigation recommendations, and carry out the licensing process with the National Telecommunication and Information Administration (NTIA) for NASA missions.

4.7 Spacecraft Search Support

In time of severe spacecraft anomaly causing the loss of communications with the ground, the DSN can provide equipment, such as a higher-power transmitter, as well as personnel to support customers in re-establishing contact with the spacecraft.

The ability to search for a lost spacecraft depends on the number of places that need to be searched, and on the signal level. There can be several dimensions in the search region: frequency, frequency rate, direction (ephemeris) and perhaps time, if the signal may be time varying. The difficulty of the search, or the time required for the search, increases approximately proportionally to the size of the search region, and inversely with the assumed minimum possible SNR.

One dimensional searches, such as just over frequency, are fairly easy, as are two-dimensional searches over limited regions, such as over small uncertainties in frequency and frequency rate or space. Large two dimensional searches are very difficult, but can be done with the custom capabilities.

The Spacecraft Search capabilities offered are further divided into 6 types of services according to the techniques, complexity, and expertise involved in service provision: Frequency and Time Searches, Spatial Search, Frequency Rate Search, Extreme Weak Signal Search, Wideband Spatial Searches, and Extremely Weak Signals with Frequency and Frequency Rate Uncertainty.

Section 5
DSN Stations – Operating Modes and Characteristics

Some of the capabilities described within this Services Catalog include multiple modes of operation and alternative configurations within their standard scope. This enables them to better suit a particular customer's requirements. This section provides some additional information describing these alternatives, as well as defining key performance characteristics. The DSN Telecommunications Link Design Handbook[29] provides a more comprehensive treatment of these topics.

A key characteristic constraint of the DSN is that the maximum received signal strength is -90 dBm. Missions *must* limit the spacecraft downlink EIRP so as to not exceed this level.

5.1 Station Characteristics

The standard configuration for Telemetry, Tracking, and Command (TT&C) is one ground antenna with dedicated telemetry, tracking, and command equipment interacting with a single spacecraft. In this configuration, dual communication links, e.g., simultaneous X- and Ka-band links, between a spacecraft and a DSN station can also be accommodated. Table 5.1, "DSN Stations and RF Capabilities" provides an overview of the available DSN stations in terms of antenna size and type, location, operating bands and signal gain.

Table 5-1. DSN Station and RF Capabilities

Antenna	Type	Location	DSS No.	Uplink		EIRP	Downlink		K GAIN / G/T[2]
Dia (m)				Uplink	Polarization	(dBW)	Downlink	Polarization	@ 45 deg (dB)
- - - - - - - - - -S-Band - - - - - - - - -									
26	E.O.[1,4]	Canberra, Australia	46	2025 - 2120 [7]	RCP or LCP	94.4	2200 - 2300	RCP & LCP or Linear	52.5 / 31.9
26	E.O.[1,4]	Madrid, Spain	66	2025 - 2120 [7]	RCP or LCP	94.4	2200 - 2300	RCP & LCP or Linear	52.5 / 31.8
34	BWG-1[1,3]	Goldstone, CA USA	24	2025 - 2120 [7]	RCP or LCP	99.1	2200 - 2300	RCP or LCP	56.8 / 41.3
34	BWG-1[1,3]	Canberra, Australia	34	2025 - 2120 [7]	RCP or LCP	99.1	2200 - 2300	RCP or LCP	56.8 / 40.8
34	BWG-1[1,3]	Madrid, Spain	54	2025 - 2120 [7]	RCP or LCP	99.1	2200 - 2300	RCP or LCP	56.8 / 41.0
34	BWG-2[1,3]	Goldstone, CA USA	25	-	-	-	-	-	-
34	BWG-2[1,3]	Madrid, Spain	55	-	-	-	-	-	-
34	BWG-3[1,3]	Goldstone, CA USA	26	-	-	-	-	-	-
34	HEF[1,3]	Goldstone, CA USA	15	-	-	-	2200 - 2300	RCP or LCP	56.0 / 40.2
34	HEF[1,3]	Canberra, Australia	45	2025 - 2110 [9]	RCP or LCP	77.8	2200 - 2300	RCP or LCP	56.0 / 40.2
34	HEF[1,3]	Madrid, Spain	65	2025 - 2110 [9]	RCP or LCP	77.8	2200 - 2300	RCP or LCP	56.0 / 39.6
34	HSB[1]	Goldstone, CA USA	27	2025 - 2120 [8]	RCP or LCP	77.1	2200 - 2300	RCP or LCP	54.8 / 34.7
70	D.S.[3]	Goldstone, CA USA	14	2110 - 2120 [7,10]	RCP or LCP	105.8 / 118.8	2270 - 2300	RCP and LCP	63.5 / 51.0
70	D.S.[3]	Canberra, Australia	43	2110 - 2120 [7,10]	RCP or LCP	105.8 / 118.8	2270 - 2300	RCP and LCP	63.5 / 50.9
70	D.S.[3]	Madrid, Spain	63	2110 - 2120 [7]	RCP or LCP	105.8 / 118.8	2270 - 2300	RCP and LCP	63.5 / 50.9

[29] DSN Telecommunications Link Design Handbook, Document No. 810-005, Rev. E, Jet Propulsion Laboratory, Pasadena, California

Antenna Dia (m)	Type	Location	DSS No.	Uplink	Uplink Polarization	EIRP (dBW)	Downlink	Downlink Polarization	K GAIN / G/T[2] @ 45 deg (dB)
- - - - - - - - - - X-Band - - - - - - - - - -									
26	E.O.[1,4]	Canberra, Australia	46	-	-	-	-	-	-
26	E.O.[1,4]	Madrid, Spain	66	-	-	-	-	-	-
34	BWG-1[1,3]	Goldstone, CA USA	24	7145 - 7190[7] 7190 - 7235[7,14]	RCP or LCP	109.9	8400 - 8500	RCP or LCP	68.3 / 52.8
34	BWG-1[1,3]	Canberra, Australia	34	7145 - 7190[7] 7190 - 7235[7,14]	RCP or LCP	109.9	8400 - 8500	RCP or LCP	68.3 / 53.7
34	BWG-1[1,3]	Madrid, Spain	54	7145 - 7190[7] 7190 - 7235[7,14]	RCP or LCP	109.9	8400 - 8500	RCP or LCP	68.3 / 53.7
34	BWG-2[1,3]	Goldstone, CA USA	25	7145 - 7190[7] 7190 - 7235[7,14]	RCP or LCP	110.0	8400 - 8500	RCP and LCP	68.4 / 53.7
34	BWG-2[1,3]	Madrid, Spain	55	7145 - 7190[7] 7190 - 7235[7,14]	RCP or LCP	110.0	8400 - 8500	RCP and LCP	68.3 / 55.3
34	BWG-3[1,3]	Goldstone, CA USA	26	7145 - 7190[7] 7190 - 7235[7,14]	RCP or LCP	109.9	8400 - 8500	RCP and LCP	68.3 / 55.5
34	HEF[1,3]	Goldstone, CA USA	15	7145 - 7190[7]	RCP or LCP	110.1	8400 - 8500[12]	RCP or LCP	68.3 / 54.0
34	HEF[1,3]	Canberra, Australia	45	7145 - 7190[7]	RCP or LCP	110.1	8400 - 8500[12]	RCP or LCP	68.3 / 54.0
34	HEF[1,3]	Madrid, Spain	65	7145 - 7190[7]	RCP or LCP	110.1	8400 - 8500[12]	RCP or LCP	68.3 / 54.0
34	HSB[1]	Goldstone, CA USA	27	-	-	-	-	-	-
70	D.S.[3]	Goldstone, CA USA	14	7145 - 7190[7]	RCP or LCP	116.1	8400 - 8500	RCP and LCP	74.5 / 62.9
70	D.S.[3]	Canberra, Australia	43	7145 - 7190[7]	RCP or LCP	116.2	8400 - 8500	RCP and LCP	74.6 / 62.8
70	D.S.[3]	Madrid, Spain	63	7145 - 7190[7]	RCP or LCP	116.3	8400 - 8500	RCP and LCP	74.6 / 63.1
- - - - - - - - - - Ka-Band - - - - - - - - - -									
26	E.O.[1,4]	Canberra, Australia	46	-	-	-	-	-	-
26	E.O.[1,4]	Madrid, Spain	66	-	-	-	-	-	-
34	BWG-1[1,3]	Goldstone, CA USA	24	-	-	-	-	-	-
34	BWG-1[1,3]	Canberra, Australia	34	-	-	-	31800 - 32300	RCP or LCP	79.0 / 65.6[13]
34	BWG-1[1,3]	Madrid, Spain	54	-	-	-	6/1/08[5,6]	RCP or LCP	79.0 / 64.4[13]
34	BWG-2[1,3]	Goldstone, CA USA	25	34200 - 34700[11]	RCP or LCP	108.5	31800 - 32300	RCP	79.0 / 64.1
34	BWG-2[1,3]	Madrid, Spain	55	-	-	-	31800 - 32300	RCP	79.1 / 65.4[13]
34	BWG-3[1,3]	Goldstone, CA USA	26	-	-	-	31800 - 32300	RCP	79.1 / 65.7[13]
34	HEF[1,3]	Goldstone, CA USA	15	-	-	-	-	-	-
34	HEF[1,3]	Canberra, Australia	45	-	-	-	-	-	-
34	HEF[1,3]	Madrid, Spain	65	-	-	-	-	-	-
34	HSB[1]	Goldstone, CA USA	27	-	-	-	-	-	-
70	D.S.[3]	Goldstone, CA USA	14	-	-	-	-	-	-
70	D.S.[3]	Canberra, Australia	43	-	-	-	-	-	-
70	D.S.[3]	Madrid, Spain	63	-	-	-	-	-	-

Notes:

1. These stations can be used for Earth Orbiting (Category A) missions
2. Performance values based on 45 deg. elevation, vacuum condition & Diplexed (if possible) single band mode
3. These stations are used for deep space (Category B) missions
4. These 26M stations will be closed in the future (FY08)
5. Planned Operational Date
6. 31800-32300 MHz
7. Transmit power range: 200 W to 20 KW (23 to 43 dBW)
8. Transmit power range: 50 W to 200 W (17 to 23 dBW)
9. Transmit power range: 50 W to 250 W (17 to 23 dBW) [this capability is to be implemented by the end of FY'08]
10. Transmit power range: 20 KW to 400 KW (43 to 56 dBW) [this capability is in the process of being decommissioned]
11. Transmit power range: 50 W to 800 W (17 to 29 dBW) [this capability will be implemented by the end of FY'10 and will cover the frequency range of 34,315 to 34,415 MHz]
12. 8200 - 8600 MHz for VLBI Service
13. Estimated values
14. Near-Earth spectrum

5.2 Alternative Station Operating Modes

DSN signal capture efficiency is influenced by several factors including: station-operating mode (diplexed v. non-diplexed), aperture size, operating frequency, and various station configurations. In addition to the standard one-station configuration, there are other alternatives. This section describes these operating modes. Note that since configuring these alternative operating modes often involves very labor-intensive activities at the DSCC, the use of any combination of them (e.g. MSPA together with arraying and MSPA with Delta-DOR observations) for a given pass or during a given period of time at a DSCC will have to be negotiated taking into account the availability of operational resources at the DSCC.

5.2.1 Multiple Spacecraft Per Antenna (MSPA)

Multiple Spacecraft Per Antenna (MSPA) is a special configuration wherein multiple receivers are connected to a single DSN antenna permitting the simultaneous reception of signals from two or more spacecraft. MSPA makes more efficient use of DSN facilities by enabling simultaneous data capture services to several spacecraft, provided that they are all within the Earth station's beamwidth. MSPA is not a service; it is a capability for resolving some schedule conflicts.

Presently, the DSN can receive signals from two spacecraft simultaneously in a 2-MSPA configuration. Capability to support up to four spacecraft simultaneously in a 4-MSPA configuration is under evaluation.

MSPA design limits uplink transmissions to a single spacecraft at a time. Thus, only one spacecraft can operate in a two-way coherent mode, all others must be in one-way non-coherent.

Only the spacecraft having the uplink can be commanded. MSPA users can agree to share the uplink, switching during the pass. Approximately 30 minutes are required to reconfigure the uplink to operate with a different spacecraft resulting in 30 minutes plus RTLT before coherent communication takes effect.

Listed below are requirements for users of MSPA:

- All spacecraft must be within the beamwidth of the requested DSN station
- All spacecraft must operate on different uplink and downlink frequencies
- Commands can only be sent to the spacecraft having the uplink
- High quality (2-way) radio metric data can only be obtained from the spacecraft operating in the coherent mode.

5.2.2 Antenna Arraying

Antenna Arraying is another special configuration wherein the signals from two or more DSN antennas are combined to create the performance of an antenna larger than either. Combining is performed at an intermediate frequency (IF) resulting in improved performance of both the carrier and data channels. Arraying 34M antennas with a 70m station improves the performance of the 70m station. When operating in the 8 GHz band, approximately five 34m stations are required in an array configuration to equal the performance of a 70m station. Arrayed operation in the S-band (2GHz) and Ka-band (32 GHz) is also supported. Like MSPA, arraying is a capability, not a service.

5.2.3 Interferometry Tracking

Interferometry Tracking is an operating mode in which two stations, each at a different DSN site, are configured to perform spacecraft tracking using a Very Long Baseline Interferometry (VLBI) technique, i.e., Delta-DOR. It allows determination of the angular position (or plane-of-sky position) of a deep space spacecraft relative to a natural radio source by measuring the geometric time delay between received radio signals at the two stations.

5.2.4 Site Diversity

Site diversity is a special configuration in which multiple sites are scheduled to improve the certainty of achieving the desired service availability. This can be done deterministically (sites are scheduled without reference to equipment or weather conditions), or adaptively (sites are scheduled on short notice only when needed). The ability to use such techniques depends strongly on the customer's ability to adapt, the availability of resources, and/or the ability to find other customers who are willing to make arrangements to relinquish their resources on short notice.

Section 6
Obtaining Services and Support

6.1 Availability

Access to the capabilities offered in this services catalog is governed by DSN Service Commitment. Generally speaking, they are available to any NASA-sponsored flight project or experiment investigation. Further, non-NASA flight projects or experiment investigations, whether US or foreign, may also avail themselves of the capabilities described herein, provided they first negotiate an agreement to that effect with NASA headquarters.

6.2 Points of Contact

The DSN Program Executive serves as the NASA Headquarters point-of-contact regarding the capabilities described herein.

The JPL DSN Mission Commitments Office serves as liaison between customers and DSN. Information on contacting the DSN Mission Commitments Office is found at this URL: http://deepspace.jpl.nasa.gov/advmiss

Customers are assigned more specific points of contact as follows:

- Future Mission Planning (FMP) Manager – during the Advanced Studies and Mission & Systems Definition phases, the FMP manager will:
  - Acquaint customers with DSN provided capabilities (both current and planned);
  - Aid customers in making early design trades (flight/ground & mission-specific/multi-mission) that are cost-effective for both the project and for NASA as a whole;
  - Assist customers with defining, negotiating, and documenting high-level support requirements, schedules, and budgets;
- Telecommunications and Mission System (TMS) Manager – starting with the Preliminary Design phase and continuing through the end of the mission, the TMS manager will:
  - Guide customers in learning what they need to know in order to effectively utilize DSN-provided capabilities;
  - Participate in customer planning and system engineering activities, in particular aiding in making more detailed design and implementation trades;
  - Assist customers in defining, negotiating, and documenting detailed support requirements, schedules, and budgets;
  - Monitor delivery, integration, and verification activities, as well as operational support, throughout the later stages of the mission life-cycle, providing visibility into these activities to both the customer and to DSN management;

The DSN Mission Commitments Office coordinates the assignment of FMP and TMS managers to customers, and ensures continuity of support throughout the life-cycle.

FMP and TMS Managers, and only FMP and TMS managers, are empowered to negotiate commitments for services and support on behalf of DSN.

6.3 Pricing

NASA has established policies which govern how costs for the capabilities described herein are allocated between multi-mission base funding and project (i.e., mission) funding. Please refer to DSN Policies and Customer Interface regarding these policies. The remainder of this section focuses on the relationship between those policies and the available multi-mission capabilities.

A "grass-roots", design-based, costing exercise is highly recommended for estimation of costs for services and support that are not covered under the Aperture Fee (see below). This is typically conducted for missions in the formulation phase by an engineering team organized through the DSN Mission Commitments Office. The customer will incur a nominal expense for this activity.

6.3.1 DSN Utilization Pricing

6.3.1.1 Pricing for Standard Data Services

Pricing for DSN utilization (i.e., standard Data Services) is based on Aperture Fees. These are computed using an empirically derived algorithm established by NASA.

Cost numbers supplied in this Section are for planning purposes only. To ensure accurate application of this information and to validate cost estimates please contact the DSN Mission Commitments Office.

The algorithm for computing DSN *Aperture Fees* embodies incentives to maximize DSN utilization efficiency. It employs *weighted hours* to determine the cost of DSN support. The following equation can be used to calculate the *hourly Aperture Fee* (AF) for DSN support.

$$AF = R_B\,[A_W\,(0.9 + F_C\ /\ 10)] \qquad \text{(equation 6-1)}$$

Where:

AF = weighted *Aperture Fee* per hour of use.

R_B = contact dependent hourly rate, adjusted annually ($1057/hr. for FY07)*.

A_W = aperture weighting:

= 0.80 for 34m High-Speed Beam Waveguide (HSB) stations.

= 1.00 for all other 34m stations (i.e., 34m BWG and 34m HEF).

= 4.00 for 70m stations.

F_C = number of station contacts, (contacts per calendar week).

*Contact the DSN Mission Commitments Office for the latest hourly rate.

Figure 6-1 below shows relative antenna costs. It graphically illustrates how *hourly costs* vary with *station contacts* and the relationships between antennas. It demonstrates the benefits of restricting the number of spacecraft-Earth station contacts each week.

A *station contact, F_C,* may be any length but is defined as the lesser of the spacecraft's: scheduled pass duration, viewperiod, or 12 hours.

For a *standard pass*, a 45-minute pre-configuration and a 15-minute post-configuration time must be added to each scheduled pass to obtain the *station contact* time (other configuration times apply to Beacon Monitoring and Delta-DOR passes – see relevant cost sections below). Note that scheduled pass-lengths should be integer multiples of 1-hour.

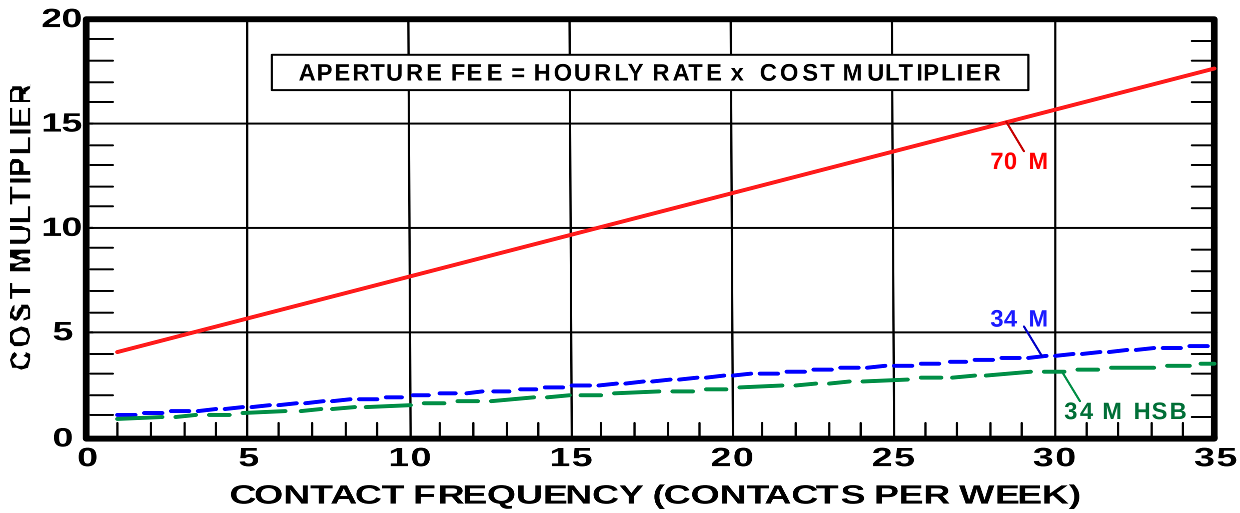

Figure 6-1. Aperture Fee Calculation

Total DSN cost is obtained by partitioning mission support into calendar weeks, grouping weeks having the same requirement in the same year, multiplying by weighted *Aperture Fee*, and summing these fees over the mission's duration. *Aperture Fees* include several services in the following categories: command, telemetry, tracking and navigation, radio science, radio astronomy, radar science, routine compatibility testing, and TMS Manager and support.

6.3.1.1.1 DSN Costing Calculations

Calculate DSN costs (*Aperture Fee, AF in $/Hr.*) by selecting a specific antenna and then determining the number and duration of tracking passes required to satisfy project commanding, telemetry, and navigation needs for launch, cruise, TCM, and science phases. Each tracking pass, except Beacon Mode, D-DOR , and a few others must be increased in length by one-hour for re-configuration. Once the pass length and number of passes is determined, multiply the aggregate hours by the hourly *Aperture Fee*, adjusted to the applicable *fiscal year,* to compute the mission's cost (in FY Dollars) using the equation above.

A form, entitled: *DSN Mission Support Costs*, can be used to calculate DSN *Aperture Fees* in real-year or fiscal year dollars. An Excel 2000 spreadsheet is available for the preparation of the cost estimates. To obtain a copy, either contact the DSN Mission Commitments Office or the DSN Future Missions Planning Office web site (http://deepspace.jpl.nasa.gov/advmiss/).

6.3.1.1.2 Included Services

The Aperture Fee covers the utilization costs for the following standard data services and engineering support:

Data Services

- Command services
- Telemetry services
- Tracking Services
- Calibration and Modeling services
- Beacon Tone service
- Radio Science services
- Radio Astronomy & VLBI services
- Radar Science Services

Engineering Support

- Systems engineering support
- Advance mission planning support
- Emergency mission operations center support
- RF compatibility test support (Compatibility Test Trailer support cost not included)
- Mission system test support
- Spectrum and frequency management support
- Spacecraft search support

Note: Costs for ground communications inherent in providing these standard services are included. See Ground Communications Interface, Section 3.8 for additional details.

6.3.1.1.3 Multiple Spacecraft Per Antenna (MSPA) DSN Costing – DSN Fee Reduction

Some flight programs, such as those surveying Mars, have clustered several spacecraft about a planet. It is possible to simultaneously capture telemetry signals from two or perhaps more spacecraft provided that they lie within the beamwidth of the Earth station's antenna.

If this situation applies and the constraints list below are acceptable, then it may be possible to reduce the Antenna cost by half for spacecraft operating without an uplink in a non-coherent mode. To calculate the cost, first compute the *Aperture Fee* using the equation 9-1 above.

For a Project to avail itself of the MSPA savings, the following constraints must apply:

- All spacecraft must lie within the beamwidth of the requested antenna.
  - Projects must accept reduced link performance from imperfect pointing.
- Spacecraft downlinks must operate on different frequencies.
- Only one spacecraft at a time can operate with an uplink in a coherent mode.
  - Commands can only be sent to the spacecraft receiving an uplink.
  - Ranging & coherent Doppler are available from the spacecraft in a 2-way mode.
  - Remaining spacecraft transmit 1-way downlinks with telemetry only.

Thereafter, apply the correction factor according to the formula:

$$AF' = (0.50)\ AF \qquad \text{(equation 6-2)}$$

Where: AF' = weighted *Aperture Fee* per hour of use for spacecraft operating without an uplink in the MSPA mode. (Spacecraft having an uplink when operating in an MSPA mode should use the aperture fee (AF) computed according to equation 6-1.)

The reduced price, AF', reflects the lack of capability resulting from no uplink communications. It is based upon the loss of commanding and ranging services to the spacecraft operating in a one-way non-coherent mode. If MSPA users agree, all could time-share the uplink and then re-allocate cost savings according to their individually negotiated sharing arrangements. When switching the uplink from one spacecraft to the next, full costs, *AF*, begin to apply to the new two-way coherent user at the onset of the switching operation.

Note: MSPA exists if, and only if, the same DSN antenna is simultaneously supporting two or more spacecraft without regard to whether an uplink is required by either.

Some examples may prove helpful. If a single DSN antenna is capturing telemetry from two spacecraft simultaneously, one with an uplink and the other in a one-way mode, the one with the uplink is at full cost (*AF*) [equation 6-1] while the other without the uplink calculates its cost at *AF' = 0.5 AF*. Where neither of the two spacecraft has an uplink, then each pays an *Aperture Fee' (AF')* of 0.5 *AF*. **If the pass of one spacecraft begins before the other, or lasts beyond another, then there is no MSPA and that user is charged the full *Aperture Fee, AF* irrespective of whether there is an uplink.** Figure 6-2 may help to clarify the rules.

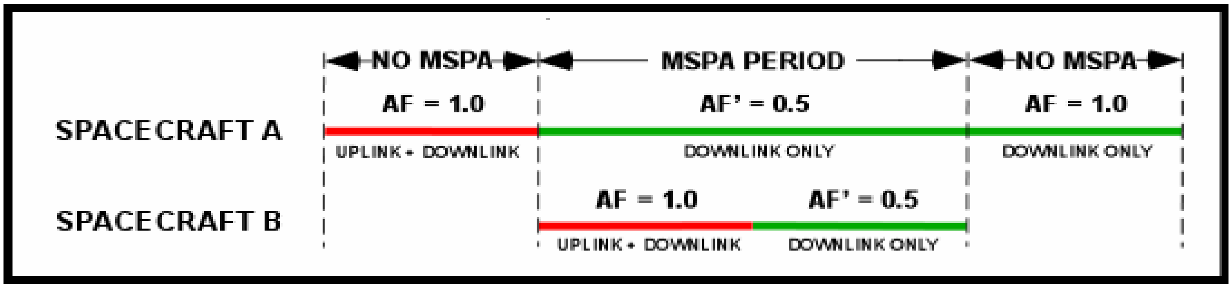

Figure 6-2. MSPA Aperture Fee

6.3.1.1.4 Clustered Spacecraft Aggregated DSN Costing

Occasionally a mission comprises several spacecraft flying in a geometric formation, but with spacing too large to utilize MSPA. Rather than request simultaneous support from several DSN stations, the project may agree to sequentially contact each spacecraft. From a project viewpoint, it is desirable to treat sequential DSN communications with several spacecraft as a single DSN contact for costing purposes. This section outlines the conditions when aggregation is permitted.

The DSN *station configuration* is a key element in establishing the continuous nature of a contact. If a new configuration is required for each spacecraft in the cluster, then support of several spacecraft assumes the character of individual contacts arranged in a sequential order. Conversely, if everything at a DSN station, except the direction in which the antenna is pointing remains fixed when transitioning to a different spacecraft, the essential character is one of a single contact.

Station configuration involves loading predicts containing: transmit and receive frequencies, Doppler frequency estimates, spacecraft identification numbers, data routing information, measuring station ranging delay, etc. These may be unnecessary when the several spacecraft:

- Operate on the same frequency,
- Have the same spacecraft identification number,
- Require identical data routing, and
- Do not utilize ranging.

For missions consisting of multiple spacecraft, each of which receives commands and/or transmits telemetry sequentially to and from a single DSN Earth station in a series of contiguous communications, then aggregation of individual pass times into a single contact may be reasonable.

Clustered Spacecraft Aggregated DSN Costs are calculated by:

- Adding a single pre-configuration and post-configuration time for the aggregated period,
- Including costs for time needed to move the spacecraft from one spacecraft to the next,
- Treating the series of links during a pass as a single contact for the costing algorithm,
- Computing the cost following equation 6-1.

All missions consisting of a cluster of spacecraft not meeting the above criteria should calculate their costs using equation 6-1 treating each sequential communication with a member of the cluster as a separate and individual contact.

6.3.1.1.5 Data Relay DSN Costing

Data between a landed object and a DSN station, which is relayed through an orbiting spacecraft, may be unaccompanied or interspersed with data from other sources. At any specific time, a DSN station may be communicating with one or more surface objects.

Pass cost can be found by calculating the time required to return the total amount of relayed data, assuming that only this data being transmitted from the orbiting relay element or by assuming 1-hour, whichever is greater.

Station configuration times need not be considered. Proposals should state their rationale and assumptions for their computed share of the DSN cost carefully, completely, and in sufficient detail so that evaluators can independently verify the computations.

6.3.1.1.6 D-DOR DSN Costing

Under the correct geometric circumstances, Delta Differential One-way Range (D-DOR) can result in a net reduction in needed tracks. This is so because adding D-DOR passes can reduce the number of contacts needed to collect long data arcs of coherent Doppler and ranging measurements necessary to compute a spacecraft's trajectory. D-DOR can also be used as an independent data source to validate orbit solutions. However, two widely separated earth stations are required simultaneously to view the spacecraft and the natural radio sources.

The DSN 34m and 70m stations can be used to collect D-DOR data. To calculate a cost for a D-DOR pass, users should determine the:

- DSN stations desired for the D-DOR pass,
- Amount of D-DOR data required to obtain the spacecraft's position,
- Pass length needed to obtain the data,
- Pre-configuration time of 45 minutes for D-DOR, same as that for a *standard pass*. The post-configuration time also remains at 15 minutes for each D-DOR pass, and
- Cost of the pass by summing the cost for the two desired DSN stations plus pre- and post-configuration times over the length of the pass.

6.3.1.1.7 Beacon Tone Monitoring DSN Costing

Beacon Tone Monitoring is a low-cost method for verifying spacecraft health. A spacecraft transmits up to four predetermined tone frequencies (subcarriers) indicating its current condition. Spacecraft must be designed to monitor their subsystems and direct an appropriate tone be transmitted. Beacon Tone Monitoring is particularly useful during long cruise periods when little or no science data is being collected.

Beacon Tone tracks (exclusive of configuration time) are generally short (40 to 60-minutes) and must occur at pre-scheduled times when the spacecraft is in view of a DSN complex. DSN 34m or 70m stations capture tones and deliver the detected tones to the mission users. They, not DSN personnel, must determine the meaning of the received tone.

Because no science or housekeeping telemetry data is received, it is possible to reduce the configuration times and hence cost for Beacon Tone Monitoring. Missions calculating a cost for Beacon tone Monitoring should compute *Aperture Fee (AF)* for the requested DSN antenna using a pre-configuration time of 15-minutes and a post-configuration time of 5-minutes (rather than 45-minutes and 15-minutes respectively). The minimum pass length, including configuration times, is 1-hour (40-minute pass plus 20-minutes of pre- and post-configuration time).

6.3.1.1.8 Compatibility Testing DSN Costing

The DSN encourages pre-launch compatibility testing as a means to eliminate post launch anomalies and expensive troubleshooting. The DSN maintains two facilities known as the Development Test Facility (DTF-21), and a Compatibility Test Trailer (CTT-22). Except for the high power transmitter, antenna, and low noise-receiving amplifier, which are not included, these facilities are configured much like an operational DSN Earth station.

Approximately eighteen months prior to launch, projects should bring their Radio Frequency Subsystems (RFS) to DTF-21 for testing. Testing requires approximately two weeks and includes such items as RF compatibility, data flow tests, and transponder calibration. However, compatibility testing does not include the ability to test Ka-band uplink, Radio Science, or Delta-DOR capabilities. Additional testing can be arranged by utilizing the CTT at the spacecraft manufacturing facility, if required.

Because the DSN believes that this testing materially improves the likelihood of mission success, no charge is made for the use of the DTF-21 facility for a single set of compatibility tests. Rather, it is included in the hourly-dependent rate, R_B, used in equation 6-1. For the use of the CTT-22 facility the only charge is to cover the travel and per-diem costs of the DSN personnel and the transportation cost of moving the test trailer to the user facility.

6.3.1.2 Pricing for Non-standard DSN Services

Some customers will require better performance than that provided by the standard data services. Similarly, "tailored" services can be provided when the standard services must be heavily customized in order to meet the customer's operations needs, or when the nature of the customer’s endeavor requires functions that are not supported by the standard services. Neither standard services with enhanced performance nor tailored services are typically covered under the Aperture Fee. In either of these cases, customers would incur additional costs as discussed under the heading of "Special/unique requirements".

6.3.2 Engineering Support Pricing

Except as otherwise noted, the customer will incur the costs of the Engineering Support Activities to which they subscribe, as negotiated through the DSN Mission Commitments Office.

6.4 Commitment Process

Policies concerning commitments of DSN capabilities to customers are defined in DSN Services Commitment Policies.

Figure 6.3, “Customer Interfaces by Phase” illustrates the various interfaces for obtaining the services and support provided by the DSN as a function of mission life-cycle phase. The diagram depicts these interfaces from the perspective of a single customer. The DSN not only concurrently supports a multitude of customers at various stages of mission life-cycle, it also undergoes continual evolution in capabilities as a consequence of the need to maintain, modernize and extend existing capabilities, as well as to develop new capabilities in anticipation of future mission needs. As a result of the evolution in capabilities, the Projects must be able to accommodate the changes in interfaces at their own expense.

The service commitments process defines the manner in which commitments between the DSN and the customer are negotiated, documented, revised, and monitored. The remainder of this section provides a brief overview of that process.

Table 6.2 identifies the various instruments of agreement and summarizes their use in terms of purpose, phasing and approval.

- The process begins in one of two ways:
    - For non-NASA projects (whether US or international), NASA headquarters negotiates the first level of agreement. This typically takes the form of either a Memorandum of Understanding (MOU) or Letter of Agreement (LOA), which sets the scope and parameters of the DSN support to the customer. The DSN Mission Commitments Office cannot begin work on any specific commitment documents until the requisite agreement is in place with NASA Headquarters.
    - For NASA-competed missions, a Letter of Commitment (LOC) is used during the Advanced Studies and Mission & System Definition phases to outline the anticipated services and estimated costs for the project.
- In either case, a Memorandum of Agreement (MOA) is used to identify and define agreements pertaining to new or tailored capabilities that will need to be developed by the DSN to support the mission.
- Information about the flight project or experiment investigation, including multi-mission service and support needs, is captured during the Advanced Studies and Mission & System Definition phases and documented in a preliminary DSN Services Agreement (DSA) Step 1. The DSA Step 1 identifies which capabilities (as described in this Services Catalog) the customer intends to use, any known parameters regarding that usage, and any negotiated exceptions or variations.
- During the Preliminary Design phase, the TMS Manager will be assigned and will begin refining the DSA Step 1, which should be finalized at the end of this phase.
- Once the mission has been confirmed by NASA Headquarters and the Design& Build phase begun, the TMS manager will begin work on the final DSN Services Agreement DSA) document. The final DSA expands on the DSA Step 1, providing details of more specific agreements in a manner that is traceable both to customer requirements and to DSN specifications. The DSA should be baselined by the mission's Critical Design Review (or equivalent). It will continue to evolve throughout the remainder of the mission life-cycle as plans and requirements are refined or changed.

During the ATLO and Operations phases, the TMS Manager will monitor delivery, integration, and verification of the agreed upon capabilities, as well as participating in investigative and resolution efforts should anything go wrong.

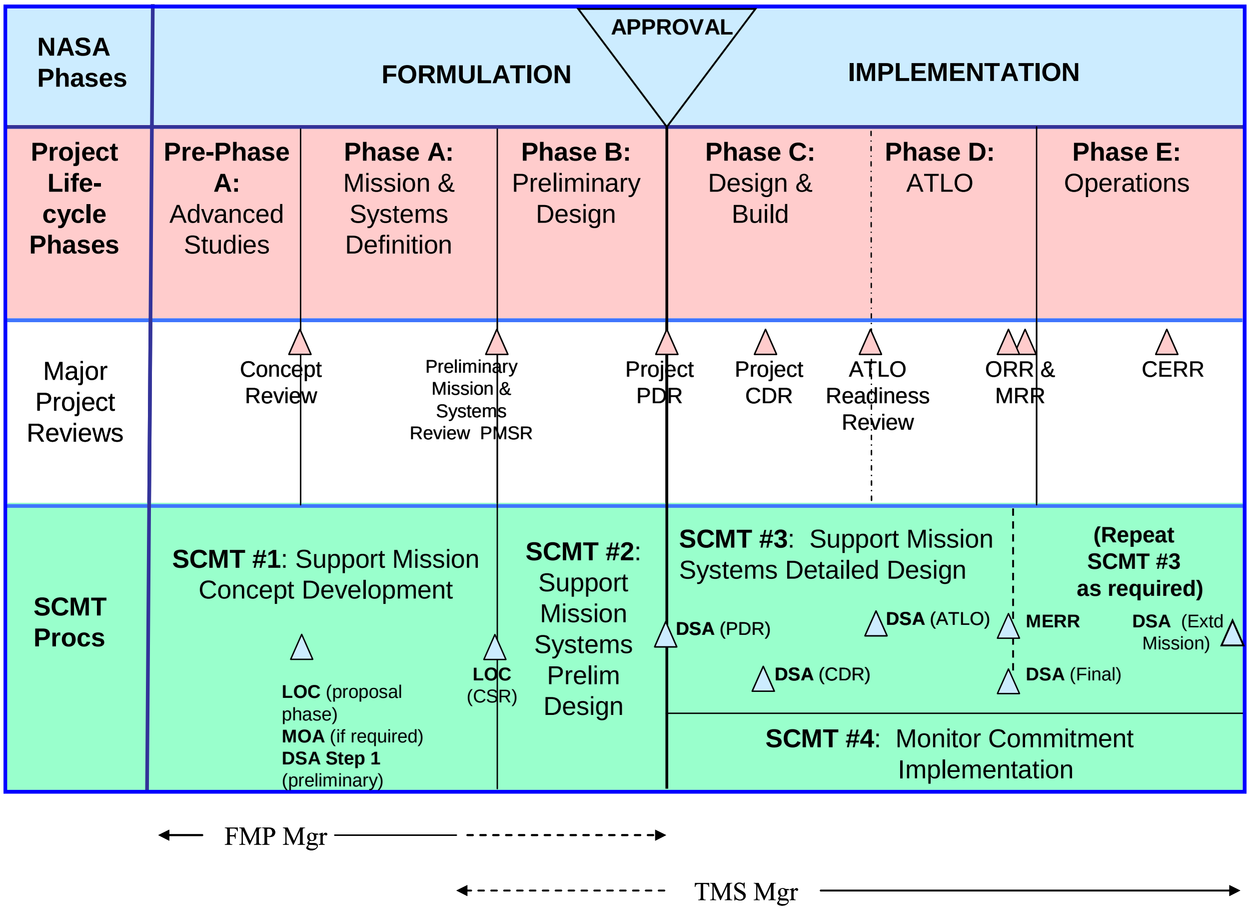

Figure 6-3. Customer Interfaces by Phase

Table 6-1. Overview of Commitment Documents

	Purpose	Availability	Owner / Approval
Letter of Commitment (LOC)	-- Competed proposals -- Typically two pages plus a budget and signature page -- Service system-level commitment based on mission concept -- Cost estimates: - Team G model-based for proposal submission - Grass-roots for CSR - Includes cost attribution for DSN tracking - Identify any new capabilities and estimate costs -- Included in "Endorsements" appendix of proposal	-- Proposal submission -- CSR submission (end of Phase A for competed missions)	-- Owner: DSN -- Approval: Director for IND
Memorandum of Agreement (MOA)	-- Non-competed missions -- Documents agreements for providing new capabilities that are beyond the scope of the baseline program -- Typically covers long lead and big ticket items	-- Typically generated in Pre-Phase A, but can be generated whenever need for new capability is identified	-- Owner: DSN -- Approval: - Project Mgr. - Program Mgr. - Director for IND
DSN Services Agreement Step 1 (DSA Step 1)	-- All missions -- Typically twenty pages -- Service system-level commitment based on preliminary mission requirements -- Provides updated cost estimates based on requirements -- Provides schedule for delivery of DSN capabilities	-- Evolves during Phase A and signed-off at the end of Phase B	-- Owner: DSN -- Approval: - TMS Mgr - Mission Commitments Office Mgr. - Project Mgr. -- Concurrence: - DSN SE Mgr. - DDOSO Mgr.
DSN Services Agreement (DSA)	-- All missions -- Typically one-hundred pages or more -- Commitments are based on detailed Project requirements -- Provides updates to budget based on signed WA's -- Provides detailed delivery schedule	-- Baseline at CDR -- Updated and re-approved as Project requirements evolve during Phase C/D -- Updated for mission extensions	-- Owner: DSN; -- Approval: - TMS Mgr. - Mission Commitments Office Mgr. - Project Mgr. -- Concurrence: - DSN SE Mgr. - DDOSO Mgr

6.4.1 Brokerage of Services

The DSN Mission Commitments Office also provides a brokerage of non-DSN services to its customers. These services include such items as ground communications capabilities provided by the NASA-wide infrastructure or other providers, Launch Early Orbit Phase (LEOP) support, backup/contingency coverage when DSN assets are not available, and Delta-DOR observations by non-DSN assets in cooperation with DSN stations. In providing these services, the DSN neither commits, guarantees, nor funds items brokered for the customer. Services brokered will be described in the customer DSA.

Missions using non-DSN services are responsible for the interface with the service providing systems. In some cases, e.g., telemetry and command service interface using CCSDS SLE protocols, Client Service Interface capabilities available at DSN may be provided.

6.5 Scheduling

Scheduling for multi-mission services and support differs, depending on the type of capability being provided.

- Data Services – Scheduling of data service instances is done via the Resource Allocation and Planning Service (RAPS). The RAPS provides Deep Space Network Mid-Range (eight weeks to six months in advance of a tracking activity) and Long-Range (from one to five years in advance) allocation planning. It includes administration of the Resource Allocation Planning Team (comprising all DSN mission customers) which negotiates conflict-free Mid-Range Allocation Plans. The RAPS Joint Users Resource Allocation Planning meetings and Resource Allocation Review Board coordinate Long-Range Planning for DSN usage. The RAPS also provides analytic studies evaluating an individual mission's tracking support request as part of the DSN commitment process. Capacity studies provide DSN management insight necessary to make informed Long-Range planning decisions. RAPS antenna downtime planning identifies mission-coordinated refurbishment or implementation opportunities.
- Engineering Support – Whether level-of-effort or for specific events, schedules for Engineering Support Activities must be negotiated and documented through the Commitment process.

It must be noted that the DSN neither allocates nor commits its antenna resources. Project tracking time allocations are performed by a committee of representatives, one from each flight project, who are known as the Joint User Resource Allocation Planning (JURAP) Committee. This Committee is generally quite successful in negotiation of antenna allocations that are acceptable to all project users.

6.6 Provisioning

Like scheduling, provisioning takes different forms depending on the capability being provided.

- **Data Services** – Figure 6.4 depicts, at high level, the interfaces involved in actual data service provision (there are also, of course, interfaces between the DSN and the customer's flight system over space links, which are not shown in the figure). Once a requested service has been scheduled, the customer interacts with the Service Management function by submitting additional service request information as needed. Typically this occurs well in advance of the pass, although there is a limited capability for "near-real-time" updates. The Service Management function interprets the request, allocates and configures the necessary assets, and provides service execution monitor and control. The customer's user function or process establishes a connection to the service instance and mission data is exchanged (this may be as simple as a file transfer), either during or subsequent to the pass.
- **Engineering Support** – There is nothing special to say about "provisioning" engineering support activities. The assigned personnel show up and do the work.

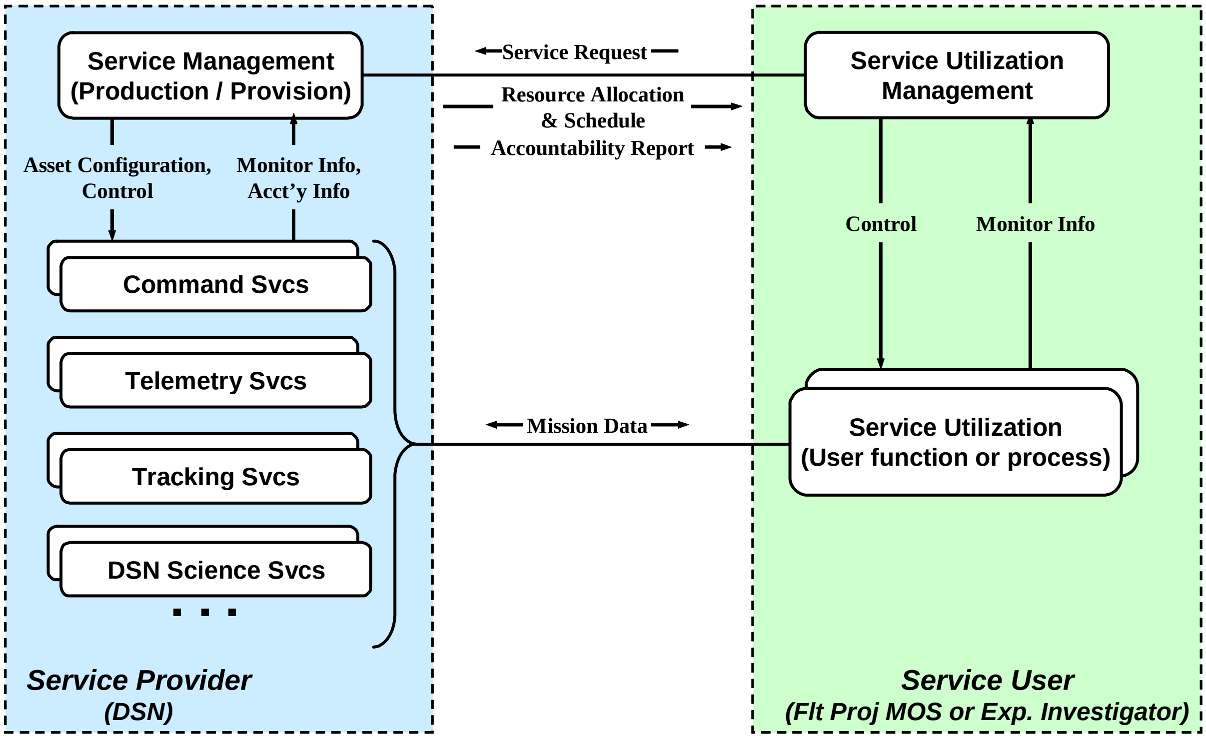

Figure 6-4. Data Service Interfaces

Appendix A
Glossary and Acronyms

AF ....Aperture Fee

AMMOS ....Advanced Multi-Mission Operations System-- a multi-mission operations system, which provides adaptable, reusable services and tools relating directly to the conduct of mission operations

AOS ....Advanced Orbiting System

Aperture Fee..................An empirically derived algorithm established by NASA for apportioning DSN utilization costs

API ....Application Program Interface

ATLO............................Assembly, Test, and Launch Operations

BWG ....Beam Waveguide

Capability......................Used generically in this Services Catalog to refer to any service and support used by missions.

CCSDS..........................Consultative Committee for Space Data Systems

CFDP ....CCSDS File Delivery Protocol

CLTU ....Command Link Transmission Units

CTT ....Compatibility Test Trailer

Customer ....An organization that acquires capabilities from the DSN office in order to conduct a flight project or experiment investigation

D-DOR..........................See Delta-DOR below

Decommissioned...........Applies to a capability or facility that is no longer supported for use by any customer

D-DOR..........................Delta-Differential One-Way Ranging

DMD ....Data Monitor and Display

DSA ....DSN Services Agreement

DSCC ....Deep Space Communications Complexes

DSN ....Deep Space Network – A multi-mission operations system which provides transport of mission data over space links, as well as observational science utilizing those links

DSN Science ....Refers collectively to Radio Science services, Radio Astronomy / VLBI services, and Radar Science services, or the to data and meta-data generated by these services

DTF ....Development Test Facility

ECC...............................Emergency Control Center

EIRP..............................Effective Isotropic Radiated Power

EOP...............................Earth Orientation Parameters

ERT...............................Earth Receive Time

FMP Manager ....Future Mission Planning Manager

GDS ....Ground Data System

GEO ....Geosynchronous Earth Orbit

HEF ....High Efficiency

IERS..............................International Earth Rotation and Reference Systems Service

IF..................................Usually Intermediate Frequency – referring to a particular region in the electromagnetic spectrum. There may be a stray occurrence or two meaning "interface"

ISO...............................International Organization for Standards

ITU...............................International Telecommunication Union

I&T...............................Integration and Test: A development activity comprising the assembly of a system from its constituent components and ensuring that the result functions as required.

K-Header.......................That part of the K-header SFDU that holds the keyword=value fields (hence, K-object) that describe the SFDU through attributes like mission, spacecraft, data type, producer, and so forth. Also called K-object or catalog header.

kbps..............................Kilo-bits per second, i.e., 1,000 bits per second (not 2^{10} or 1024 bits per second)

Mbps.............................Mega-bits per second, i.e., 10^6 or 1,000,000 bits per second

MERR...........................Mission Events Readiness Review

Mission..........................Used generically in the Services Catalog to refer to a flight project, an experiment investigation conducted in conjunction with a flight project, or an experiment investigation using the DSN as a science instrument

Mission Data.................Data that is transported via space-ground communications link, or is derived from observation of that link. Includes command data (but not all information pertaining to command preparation), telemetry (level 0 or thereabouts), tracking data (but not navigation data) and DSN science data

MOC.............................Mission Operations Center

MOS.............................Mission Operations System

MSA.............................Mission Support Area

MSPA...........................Multiple Spacecraft Per Antenna

NASA...........................National Aeronautics and Space Administration

NISN............................NASA Integrated Service Network

NOCC...........................Network Operation Control Center

PCD..............................Project Commitment Document

PSLA.............................Project Service Level Agreement

QoS...............................Quality of Service – A defined level of performance in a communications channel or system (or, more generally in an information system)

QQC.............................Quality, Quantity, and Continuity

QQCL...........................Quality, Quantity, Continuity and Latency

RF.................................Radio Frequency

ROC..............................Remote Operations Center

RTLT............................Round-Trip-Light-Time

SCMT...........................Service Commitment (process)

Service..........................A self-contained, stateless function which accepts one or more requests and returns one or more responses through a well-defined, standard interface

SFCG............................Space Frequency Coordination Group

SFDU............................Standard Formatted Data Unit

SLA...............................Service Level Agreement

SLE ....Space Link Extension
SNR...............................Signal-to-Noise Ratio
SPC ....Signal Processing Center
SPE................................Sun-Probe-Earth or Sun-Spacecraft-Earth angle
SPICE............................Spacecraft, Planet, Instrument, C-matrix, Events
SPK ....Spacecraft/Planet Kernel (SPICE Ephemeris Subsystem file)
TMS Manager ....Telecommunications & Mission Systems Manager
TT&C............................Tracking, Telemetry, and Command
User ....A person participating in flight project mission operations or an experiment investigation who interacts directly with services or support provided by DSN
UTC ....Coordinated Universal Time
VCDU ....Virtual Channel Data Units
VLBI ....Very Long Baseline Interferometry
VPN ....Virtual Private Network

Appendix B
Document Information

B.1 Effectivity

This Services Catalog is effective immediately upon its release. It supercedes DSMS Services Catalog, Version 7.5, by Wallace Tai, dated 19 May 2003, as well as all previous versions.

B.2 References

A Guide to Capabilities Provided by the Office of Space Communications: NASA Office of Space Communications. April 12, 1996.

Space Link Extension Return All Frames Service Specification, CCSDS 911.1, Red Book, Issue 1.7. September 1999.

Space Link Extension Return Virtual Channel Frames Service Specification, CCSDS 911.2, Red Book, Issue 1.7. September 1999.

Space Link Extension Forward CLTU Service Specification, Red Book, CCSDS 912.1, Issue 1.99h. February 2000.

Telecommand (TC) Space Link Protocol, CCSDS 232.0-B-1

Telemetry (TM) Space Data Link Protocol, CCSDS 132.0-B-1

Telemetry (TM) Space Packet Protocol, CCSDS 133.0-B-1

CCSDS File Delivery Protocol (CFDP), CCSDS 727.0-B-2, Blue Book. October 2002.

Packet Telemetry Services, CCSDS 103.0-B-1. Blue Book. Issue 1. May 1996.

"Low-Rate Telecommand Systems" in Radio Frequency and Modulation System, Part 1 - Earth Stations and Spacecraft, CCSDS 401.0-B. June 2001.

"Medium-Rate Telecommand Systems" in Radio Frequency and Modulation System, Part 1 - Earth Stations and Spacecraft, CCSDS 401.0-B. June 2001.

Advanced Orbiting Systems (AOS) Space Data Link Protocol, CCSDS 732.0-B-2

Advanced Orbiting Systems, Networks and Data Links: Architectural Specification, CCSDS 701.0-B-2. Blue Book. Issue 2. November 1992.

Orbit Data Messages. CCSDS 502.0-R-1. Red Book. Issue 1. June 2001.

Telemetry Channel Coding, CCSDS 101.0-B-5, Blue Book. June 2001.

Time Code Formats, CCSDS 301.0-B-3, Blue Book. January 2002.

Deep Space Network / Detailed Interface Design, Document No. 820-013, Jet Propulsion Laboratory, Pasadena, California.

Deep Space Network / Detailed Interface Design, Document No. 820-013, CMD-4-9, "Command Radiation Service – Throughput Stream Mode Protocol". July 2000.

Deep Space Network / Detailed Interface Design, Document No. 820-013, 0163-Telecomm, “SLE Forward Link Service and Return Link Service”, Rev. B. December 2006.

Deep Space Network / Detailed Interface Design, Document No. 820-013, 0188-Telecomm-CFDP, “Transaction Log File Interface”. April 2004.

Deep Space Network / Detailed Interface Design, Document No. 820-013, 0161-Telecomm, "Telemetry SFDU Interface". November 2002.

Deep Space Network / Detailed Interface Design, Document No. 820-013, 0172-Telecomm, "SFDU CHDO Structures". May 2006.

Deep Space Network / Detailed Interface Design, Document No. 820-013, 0162-Telecomm, "Beacon Telemetry SFDU Interface". July 2004.

Deep Space Network / Detailed Interface Design, Document No. 820-013, TRK-2-34, "DSN Tracking System, Data Archival Format", Rev. I. September 2006.

Deep Space Network / Detailed Interface Design, Document No. 820-013, TRK-2-18, "Tracking System Interfaces - Orbit Data File Interface", Rev. D. December 2006.

Deep Space Network / Detailed Interface Design, Document No. 820-013, TRK-2-20, "DSN Tracking System Universal Tracing Data Interface". October 1994.

Deep Space Network / Detailed Interface Design, Document No. 820-013, TRK-2-21, "DSN Tracking System, Earth Orientation Parameters Data Interface". August 1995.

Deep Space Network / Detailed Interface Design, Document No. 820-013, TRK 2-23 "Media Calibration Interface", Rev. A. July 2006.

Deep Space Network / Detailed Interface Design, Document No. 820-013, TRK-2-33, "Tracking and Navigation SPK File Interface", Rev. A, January 2006.

Deep Space Network / Detailed Interface Design, Document No. 820-013, OPS-6-12, "Remote Mission Operations Centers and 26-Meter Project/User Interface to the DSN Schedule and Sequence of Events Generation", June 2003.

Deep Space Network / Detailed Interface Design, Document No. 820-013, OPS-6-13, "Flight Project Interface to the DSN for Sequence of Events Generation", Rev. D, Apr 2005.

Deep Space Network / Detailed Interface Design, Document No. 820-013, 0168-Service_Mgmt, "DSMS Web Portal Services", May 2006

Deep Space Network / Detailed Interface Design, Document No. 820-013, 0159-Science, "Radio Science Receiver Standard Formatted Data Unit", Rev. A, June 2004.

DSN Telecommunications Link Design Handbook, Document No. 810-005, Rev. E, Jet Propulsion Laboratory, Pasadena, California. Online at:http://eis.jpl.nasa.gov/deepspace/dsndocs/810-005/

NASA's Mission Operations and Communications Services, JPL D-22674, revised 8 April 2005.

Telecommunications and Mission Operations Directorate Operations Contingency Plan, Rev. B, Document No. 801-202.

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